US005850806A

United States Patent [19]

Mark et al.

[11] **Patent Number: 5,850,806**

[45] **Date of Patent: Dec. 22, 1998**

[54] **CONTROLLABLE STROBE LIGHT SYSTEM AND METHOD FOR DIRECTING THE MOVEMENTS OF FISH**

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[73] Assignee: **Flash Technology Corporation of America**, Brentwood, Tenn.

[21] Appl. No.: **766,192**

[22] Filed: **Dec. 12, 1996**

[51] **Int. Cl.**[6] **A01K 61/00**

[52] **U.S. Cl.** **119/219**

[58] **Field of Search** 119/174, 219, 119/200, 201, 215, 216

[56] **References Cited**

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"A Demonstration of Strobe Lights to Repel Fish".
Species of Fish Showing Avoidance Response to Strobe Lights.
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Behavioral Barriers.
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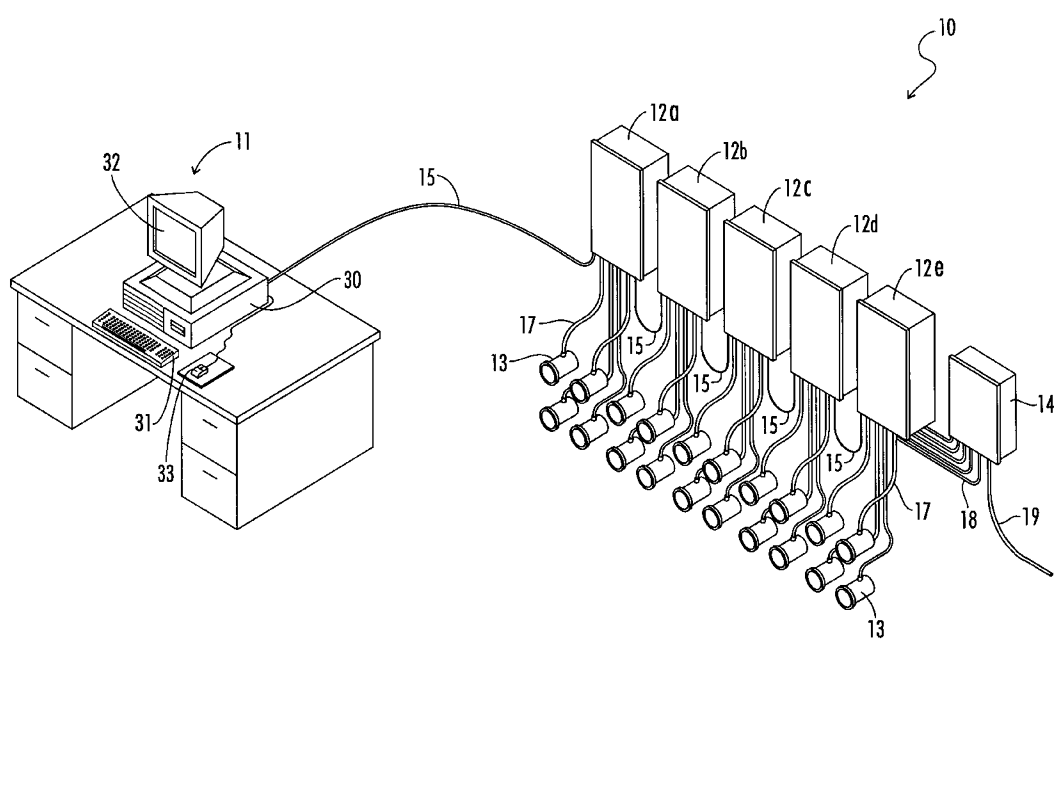
Response of Juvenile Coho & Chinook Salmon to Strobe & Mercury Vapor Lights.
"Innovators with Epritechnology" Jul. 1992.
"Cost Effective Approaches for Protecting Fish at Hydroelectric Projects" HCI Publications 1992.
"Evaluation of Study Techniques to Assiss . . . ".
"A Demonstration of Strobe Lights to Repel Fish" Water Power '91.
"Species of Fish Showing Avoidance Response to Strobe Lights" EPRI May 1994 .
"Shad Project at York Havin Shows Results" Met–Ed New. Oct. 22, 1991.
"Guiding American Shad w/Strobe Lights" Hydro Review Jul. 1992.
"Response of Juvenile Coho and Chinook Salmon . . . "NAJM 1992.
"Fishing Behavior" Fishing Behaviors.

Primary Examiner—Thomas Price
Attorney, Agent, or Firm—Waddey & Patterson; Mark J. Patterson

[57] **ABSTRACT**

A system for directing fish away from danger points at an underwater structure includes multiple submersible flash heads operatively connected to a flash head control unit. The flash sequence, rate and intensity are adjustable by the system operator in real time using a system control unit which can be remotely located. The flash heads are strobed in a manner intended to alter the behavior of the fish. The system may include means to generate an air curtain near the flash heads to improve light dispersion and water jet means to clean the lenses on the flash heads.

21 Claims, 57 Drawing Sheets



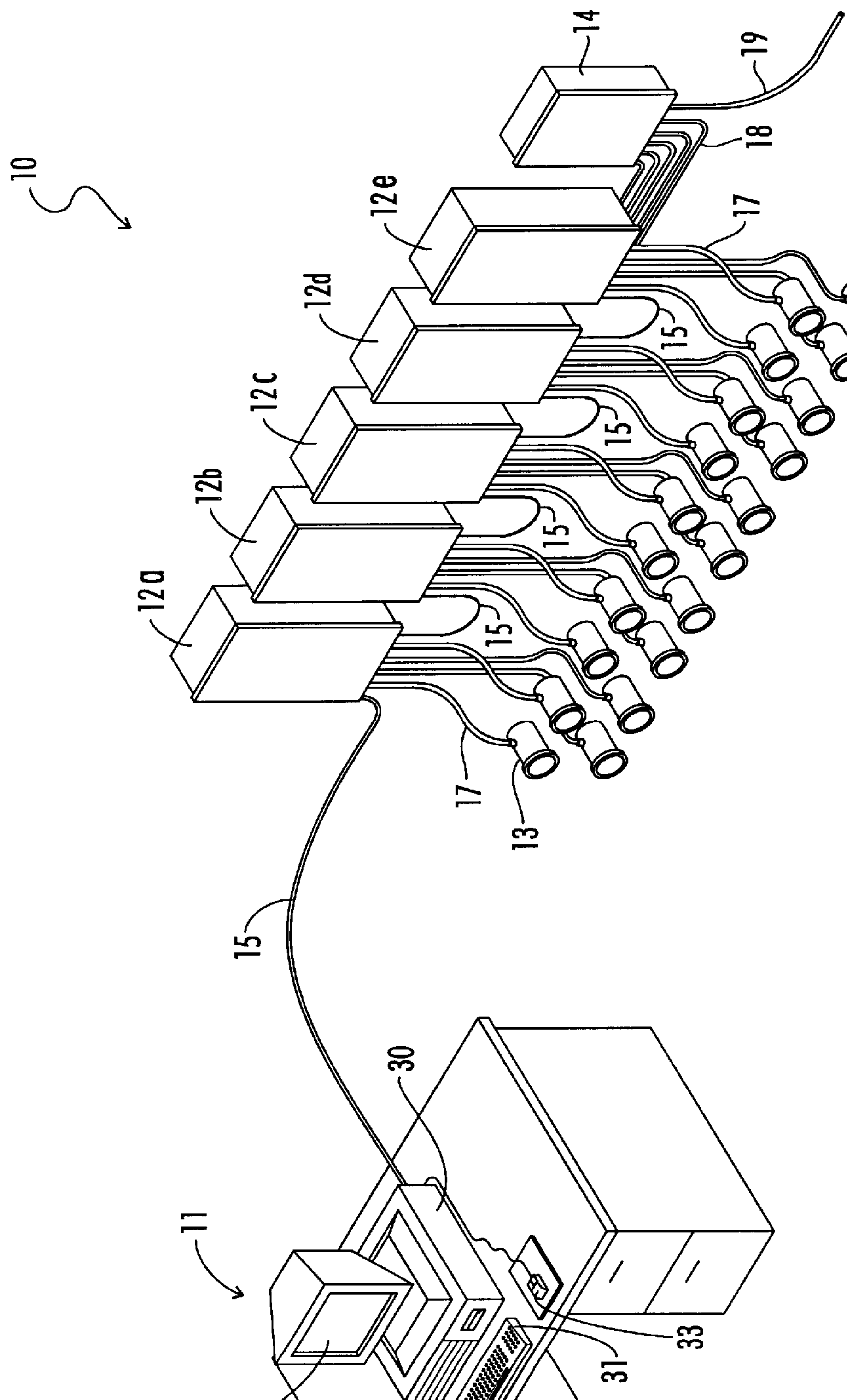
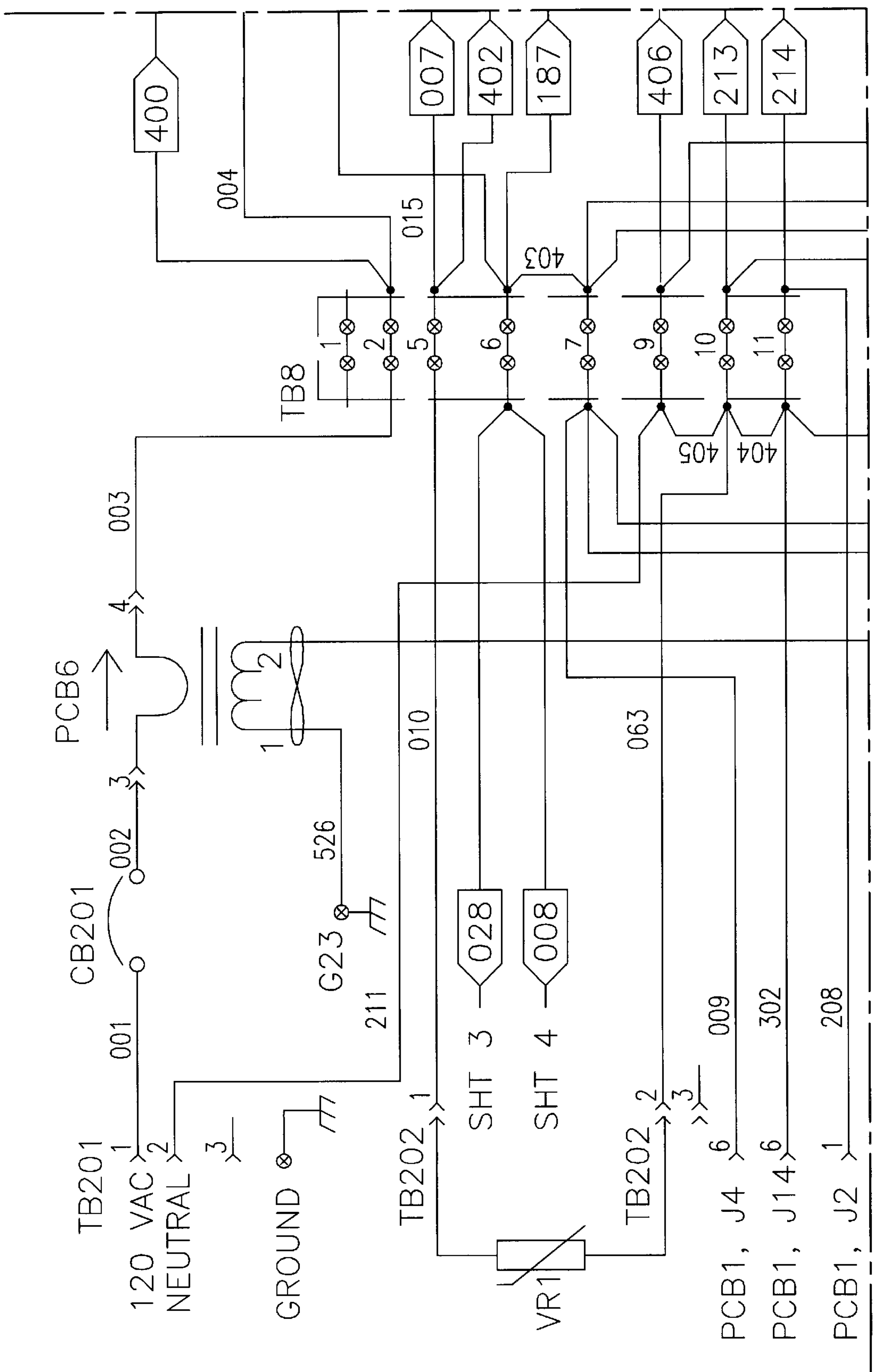


FIG. 1

FIG. 2a1	*FIG. 2a2*	*FIG. 2a3*
FIG. 2a4	*FIG. 2a5*	*FIG. 2a6*
FIG. 2a7	*FIG. 2a8*	*FIG. 2a9*

FIG. 2a



400
004
007
402
187
406
213
214
015
403
TB8
003
405
404
PCB6
CB201
002
001
526
G23
211
010
063
028
008
SHT 3
SHT 4
009
302
208
TB201
120 VAC
NEUTRAL
GROUND
TB202
TB202
VR1
PCB1, J4
PCB1, J14
PCB1, J2

FIG. 2a1

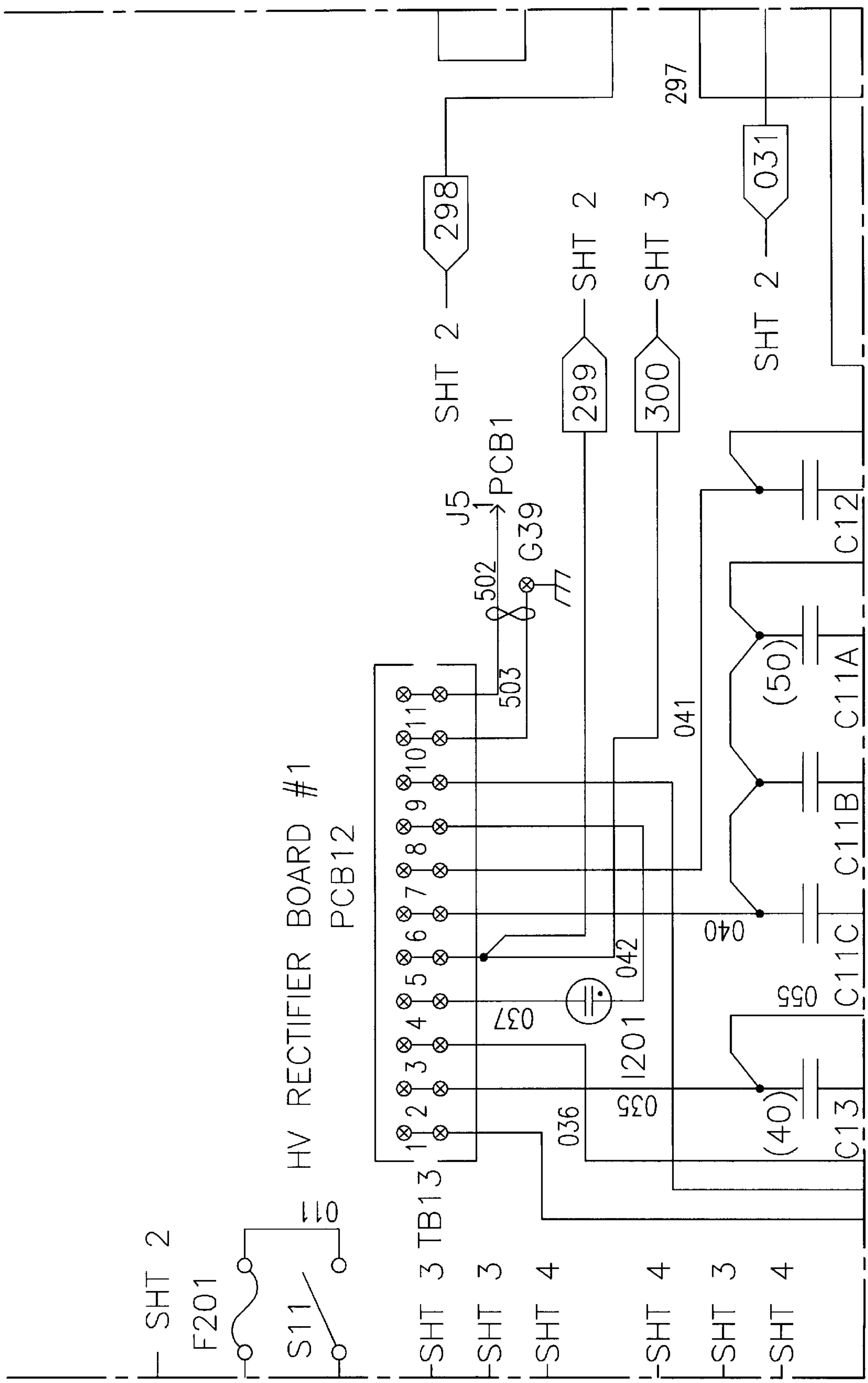

HV RECTIFIER BOARD #1
PCB12
TB13
J5
PCB1
G39
502
503
SHT 2
298
297
031
299
300
SHT 3
041
040
042
037
036
035
055
I201
(50)
(40)
C12
C11A
C11B
C11C
C13
F201
S11
011
SHT 4

FIG. 2a2

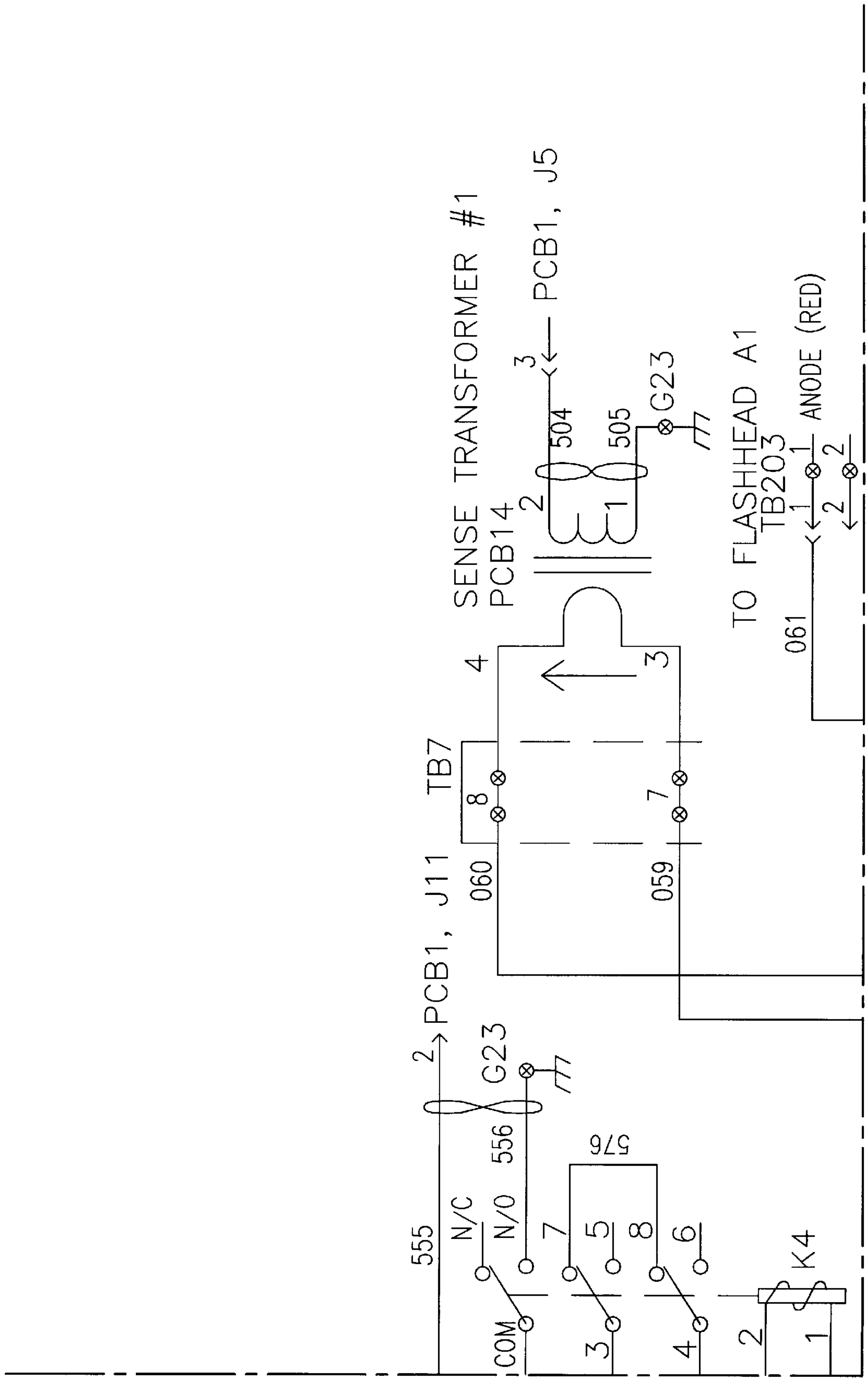

SENSE TRANSFORMER #1
PCB14
PCB1, J5
PCB1, J11
TB7
504
505
G23
TO FLASHHEAD A1
TB203
ANODE (RED)
060
059
061
555
556
576
N/C
N/O
COM
K4

FIG. 2a3

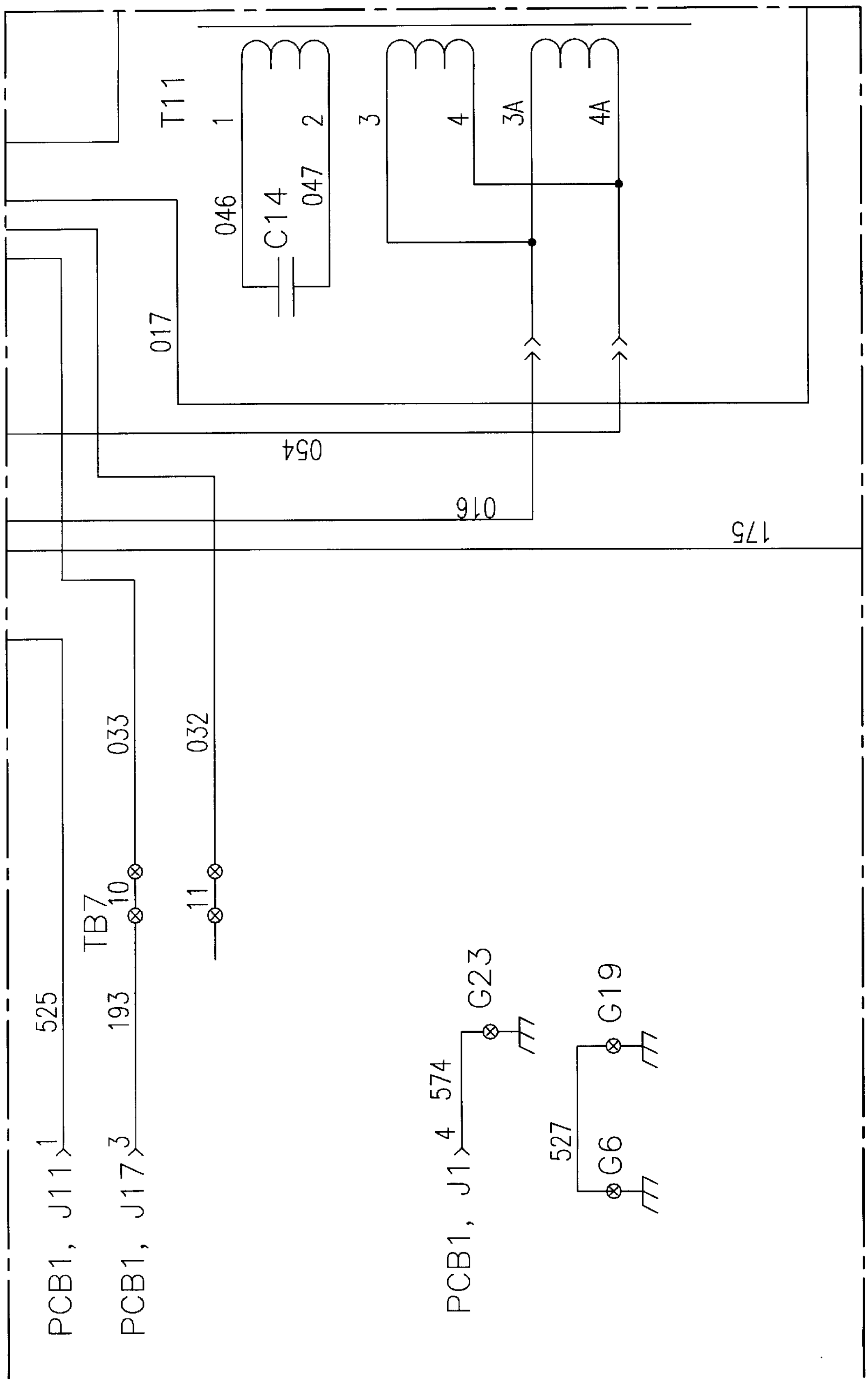

T11
1
2
3
4
3A
4A
046
C14
047
017
054
016
175
033
032
TB7
10
11
525
193
PCB1, J11
1
PCB1, J17
3
G23
574
4
PCB1, J1
G19
527
G6

FIG. 2a4

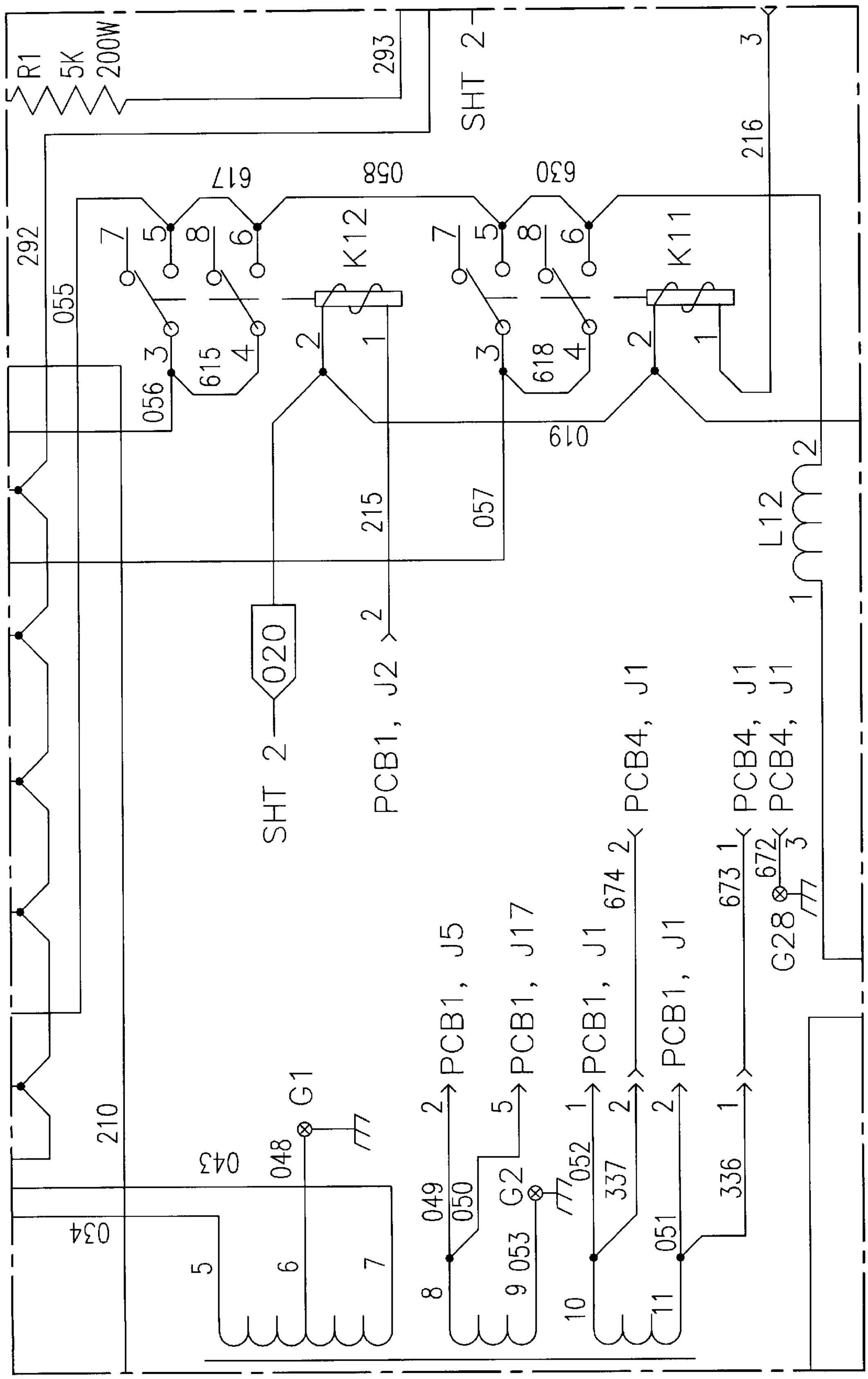

R1
5K
200W
293
SHT 2
3
216
292
055
617
058
630
7
5
8
6
K12
K11
3
615
4
2
1
618
056
019
2
L12
1
215
057
020
SHT 2
PCB1, J2
PCB4, J1
PCB4, J1
PCB4, J1
674
673
672
G28
210
G1
043
048
034
PCB1, J5
PCB1, J17
PCB1, J1
PCB1, J1
049
050
G2
052
337
336
051
053
8
9
10
11
5
6
7

FIG. 2a5

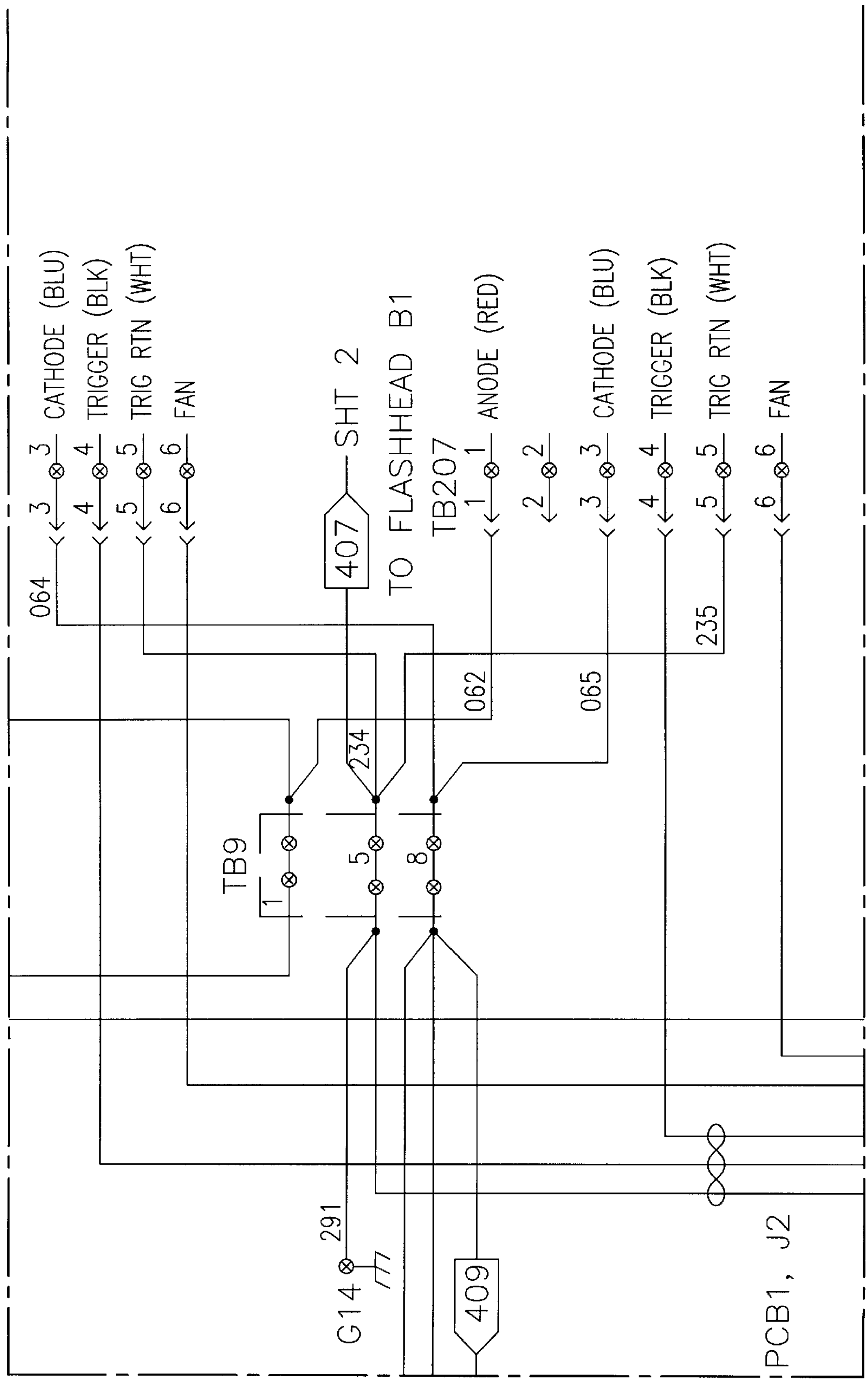

3 CATHODE (BLU)
4 TRIGGER (BLK)
5 TRIG RTN (WHT)
6 FAN
407
SHT 2
TO FLASHHEAD B1
TB207
1 ANODE (RED)
2
3 CATHODE (BLU)
4 TRIGGER (BLK)
5 TRIG RTN (WHT)
6 FAN
064
235
062
065
234
TB9
1
5
8
291
G14
409
PCB1, J2

FIG. 2a6

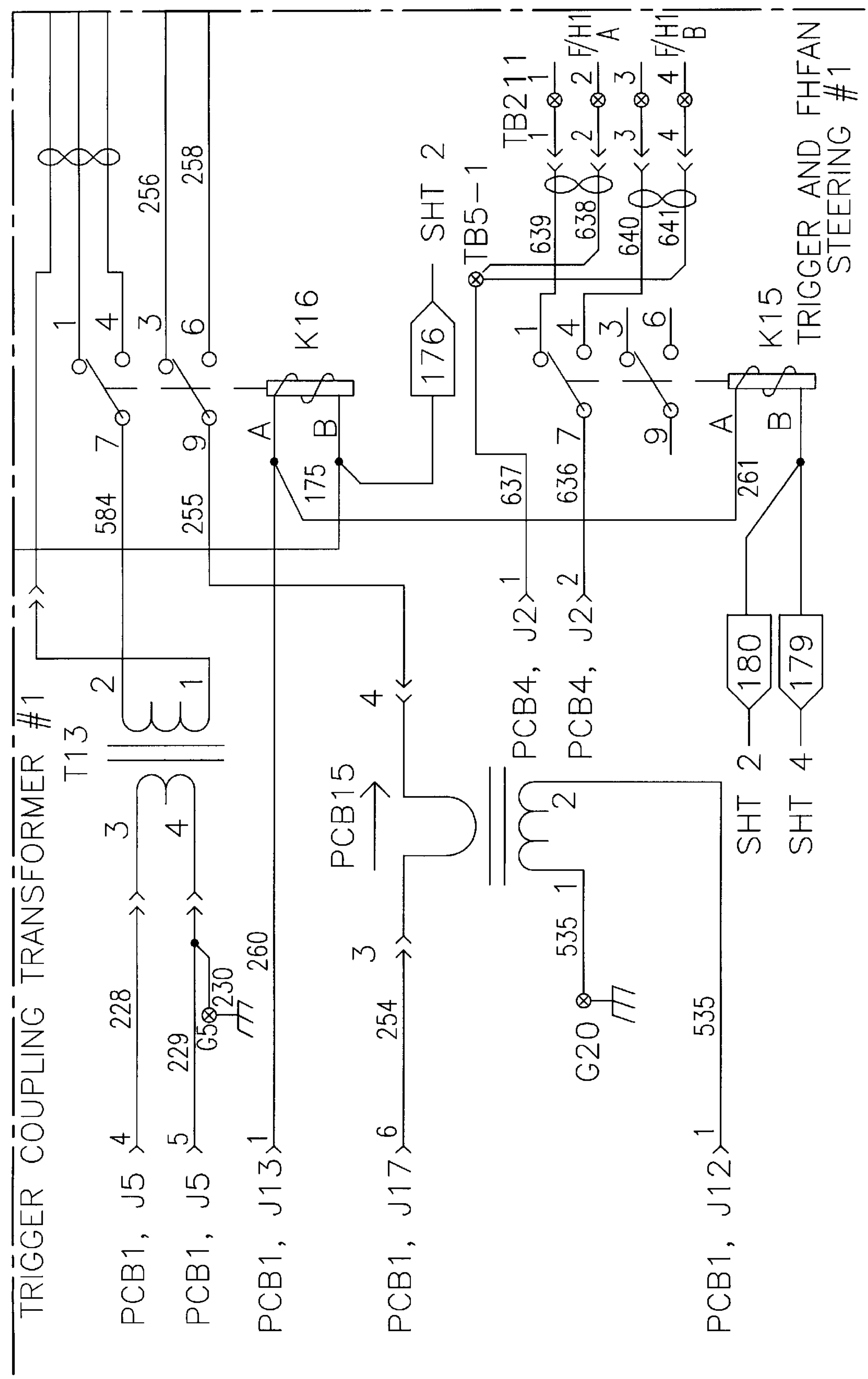

TRIGGER COUPLING TRANSFORMER #1
T13
PCB1, J5
PCB1, J5
PCB1, J13
PCB1, J17
PCB1, J12
PCB15
PCB4, J2
PCB4, J2
K16
K15
176
180
179
SHT 2
SHT 2
SHT 4
TB5-1
TB211
F/H1 A
F/H1 B
G20
G5
TRIGGER AND FHFAN STEERING #1
228
229
230
260
254
535
584
255
256
258
175
637
636
261
639
638
640
641

FIG. 2a7

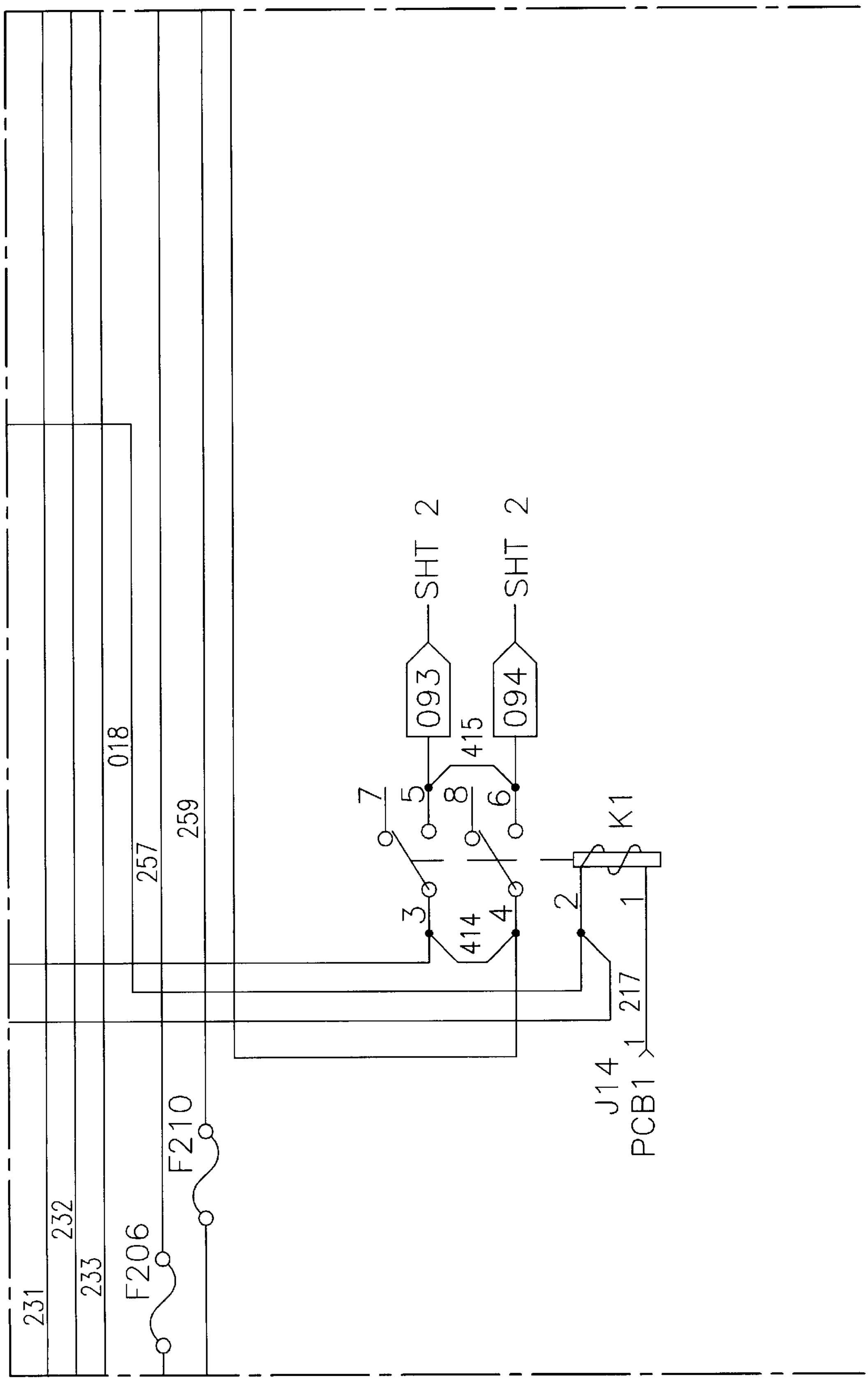

231
232
233
F206
F210
257
259
018
3
4
414
7
5
8
6
415
093
094
SHT 2
SHT 2
K1
2
1
217
J14
PCB1
1

FIG. 2a8

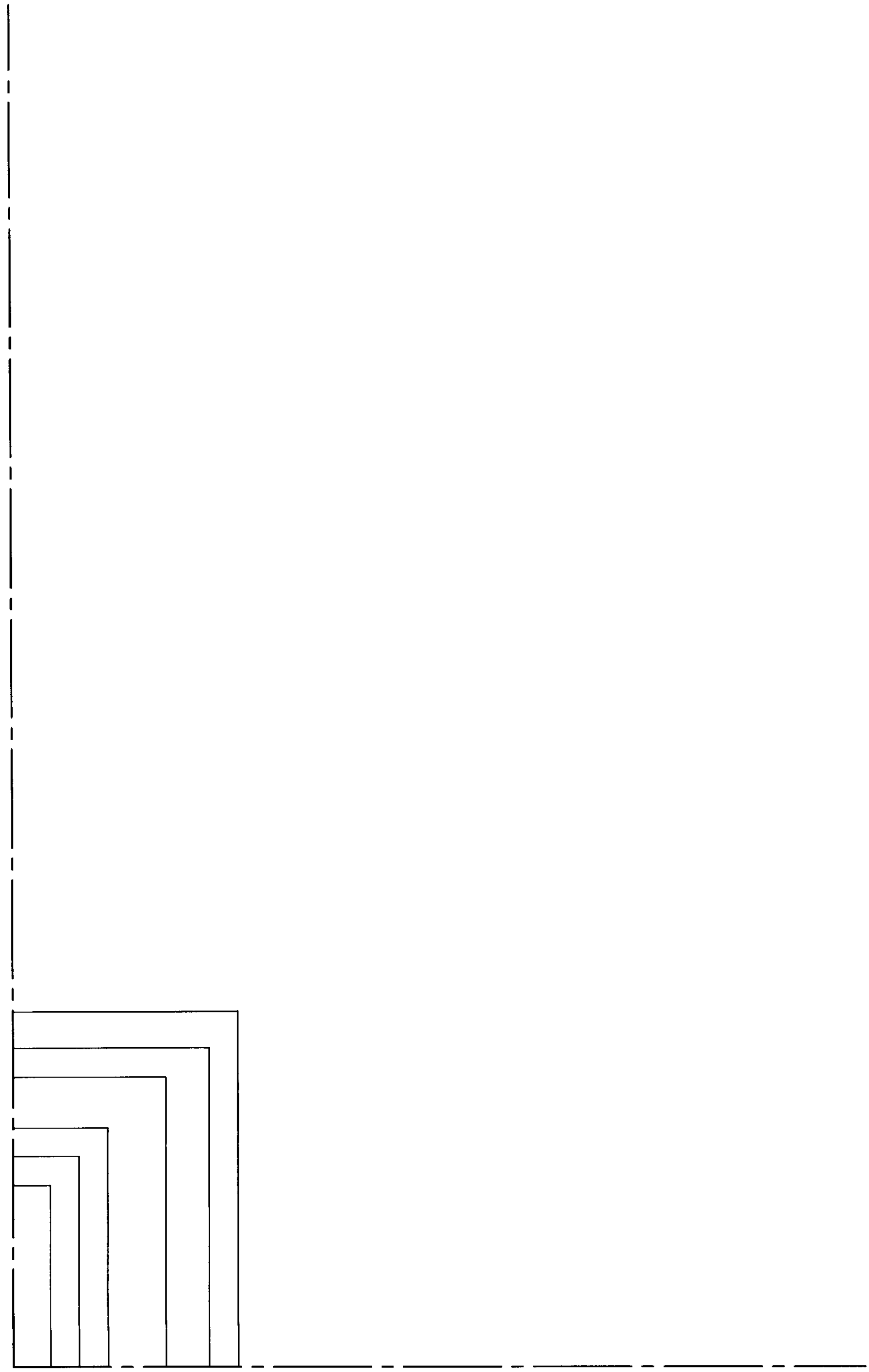


FIG. 2a9

FIG. 2b1	*FIG. 2b2*	*FIG. 2b3*
FIG. 2b4	*FIG. 2b5*	*FIG. 2b6*
FIG. 2b7	*FIG. 2b8*	*FIG. 2b9*

FIG. 2b

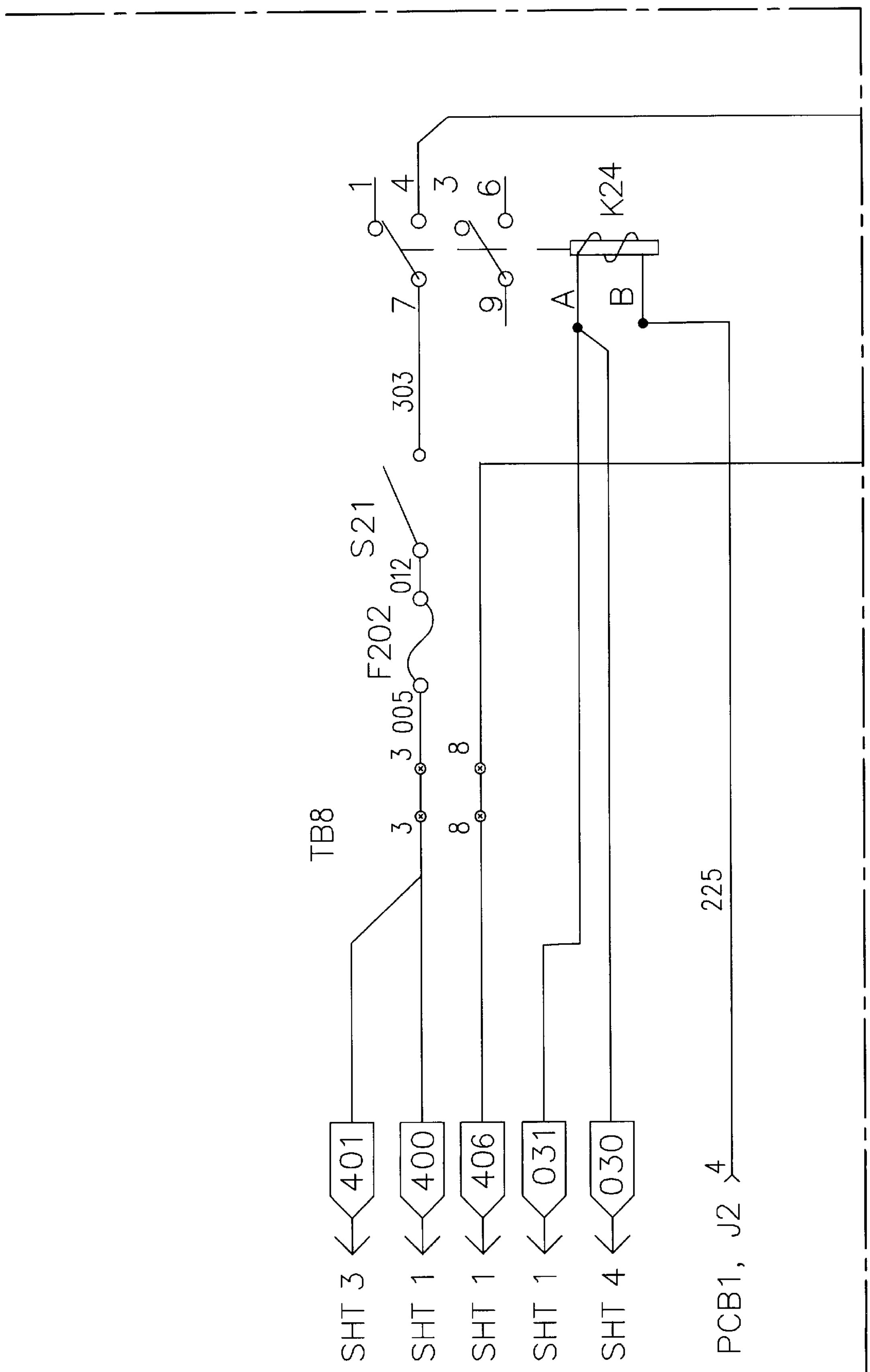

TB8
3
3
8
8
005
F202
012
S21
303
7
1
4
3
6
9
A
B
K24
225
401
400
406
031
030
SHT 3
SHT 1
SHT 1
SHT 1
SHT 4
PCB1, J2
4

FIG. 2b1

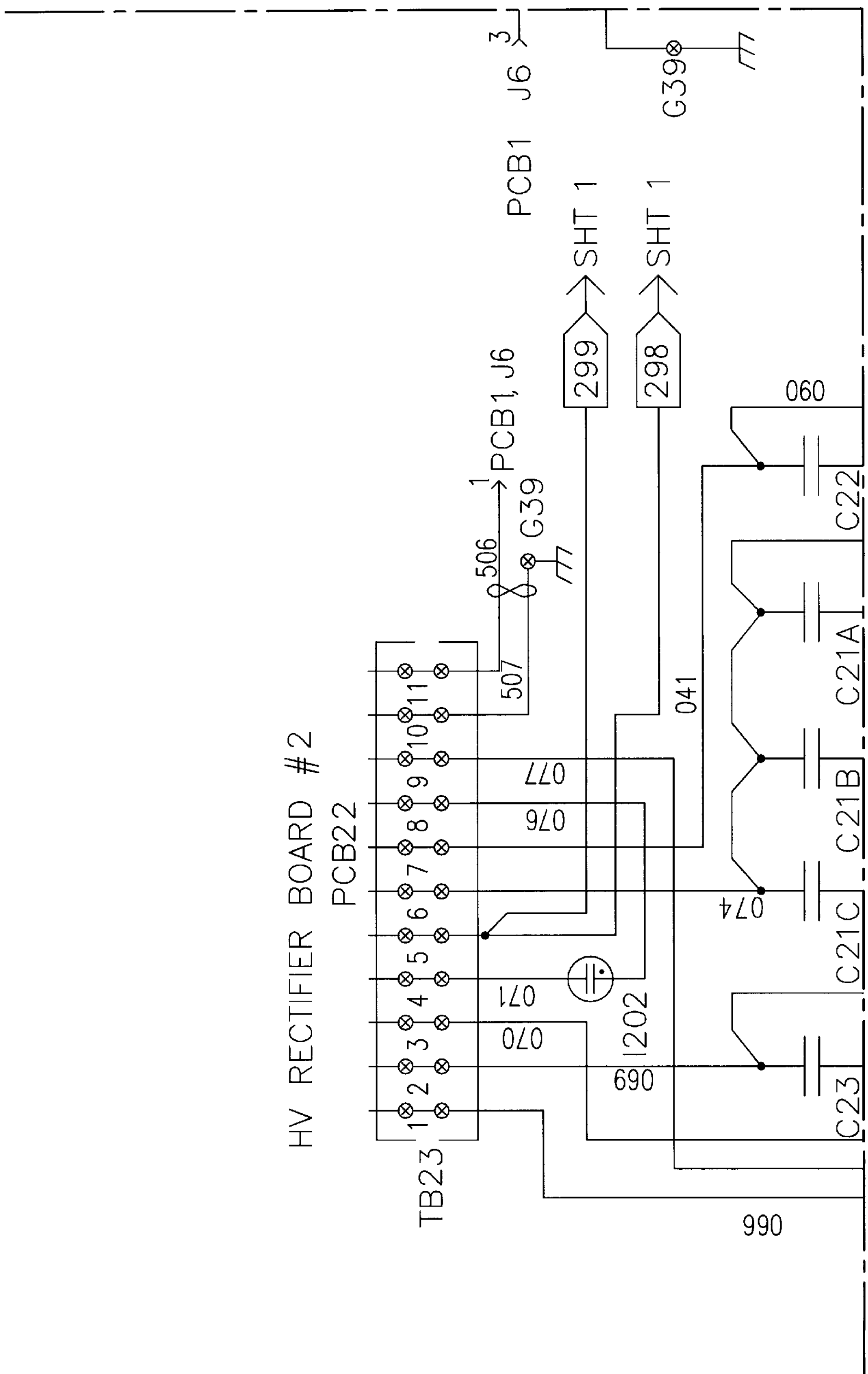

HV RECTIFIER BOARD #2
PCB22
TB23
PCB1 J6
PCB1, J6
G39
SHT 1
299
298
506
507
060
041
077
076
074
071
070
1202
C22
C21A
C21B
C21C
C23

FIG. 2b2

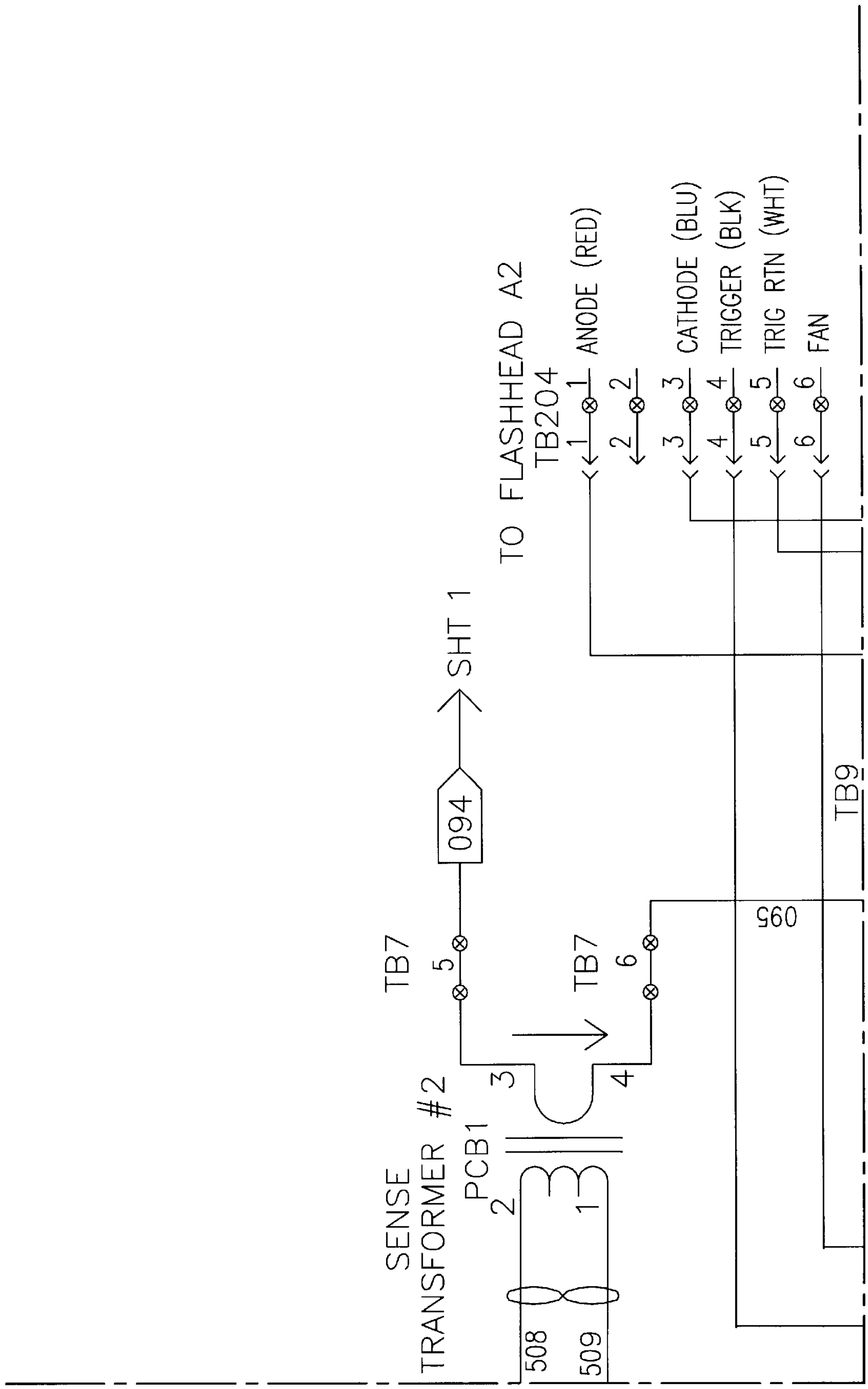

SENSE TRANSFORMER #2
PCB1
508
509
TB7
TB7
094
SHT 1
095
TB9
TO FLASHHEAD A2
TB204
ANODE (RED)
CATHODE (BLU)
TRIGGER (BLK)
TRIG RTN (WHT)
FAN

FIG. 2b3

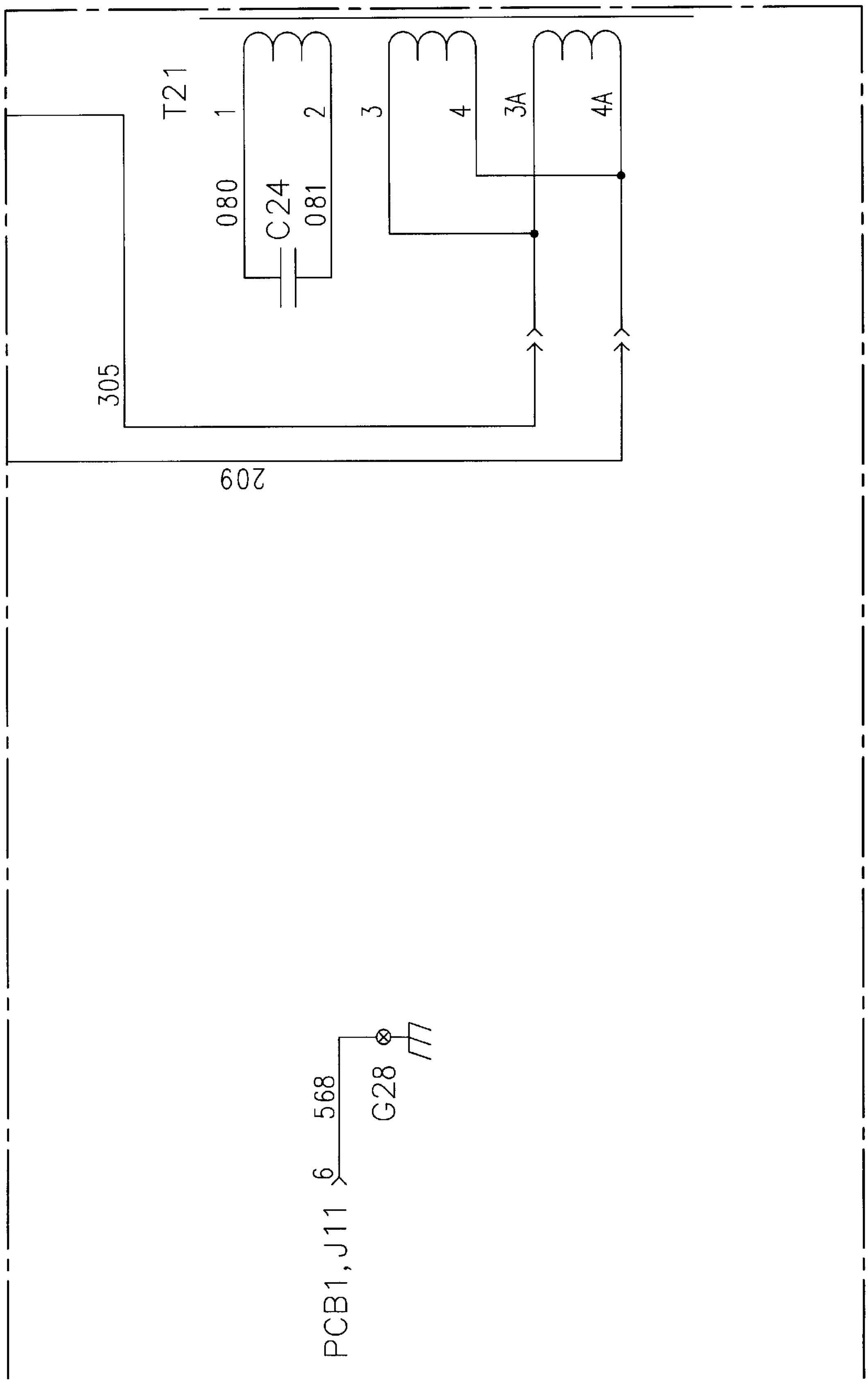


FIG. 2b4

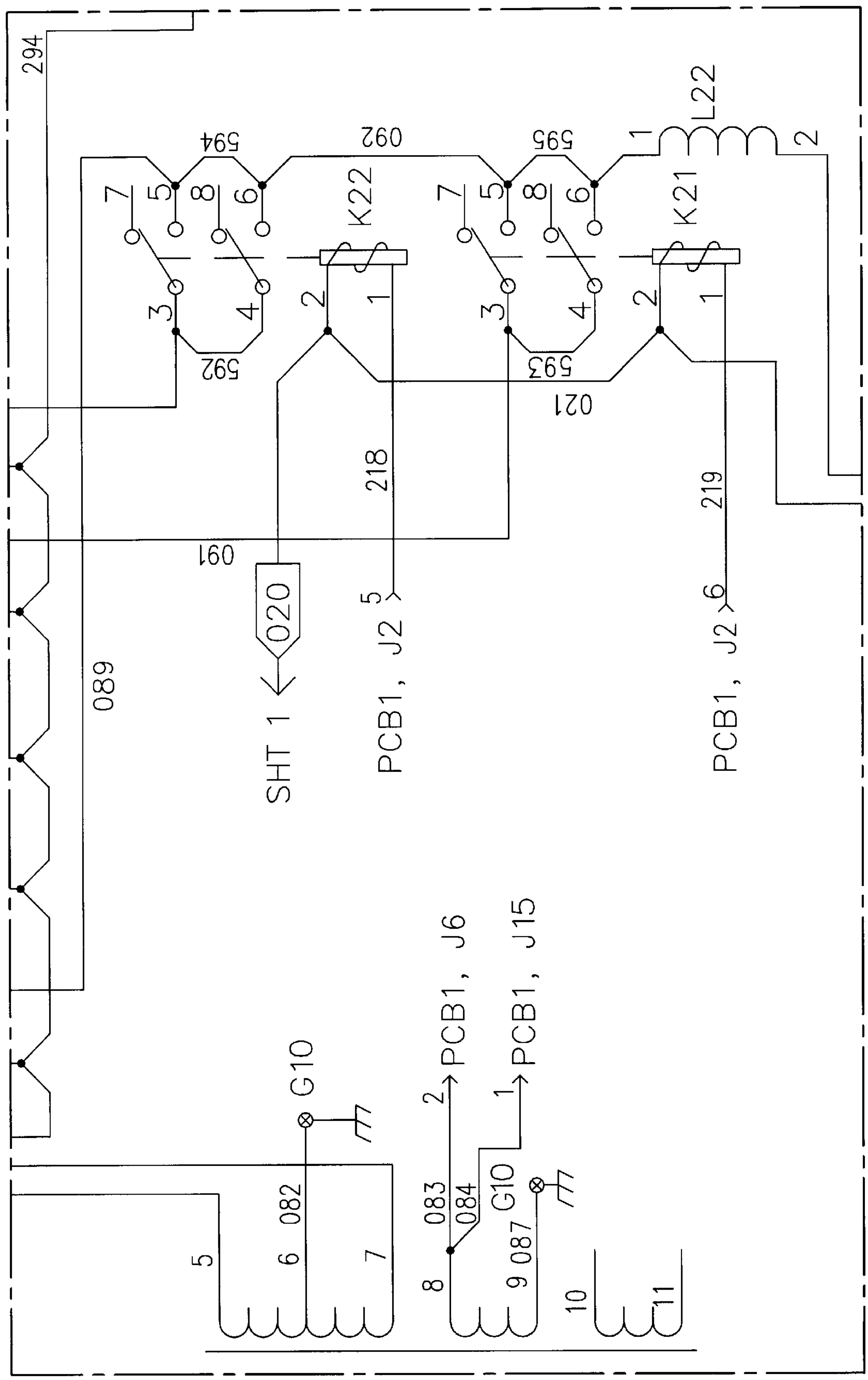
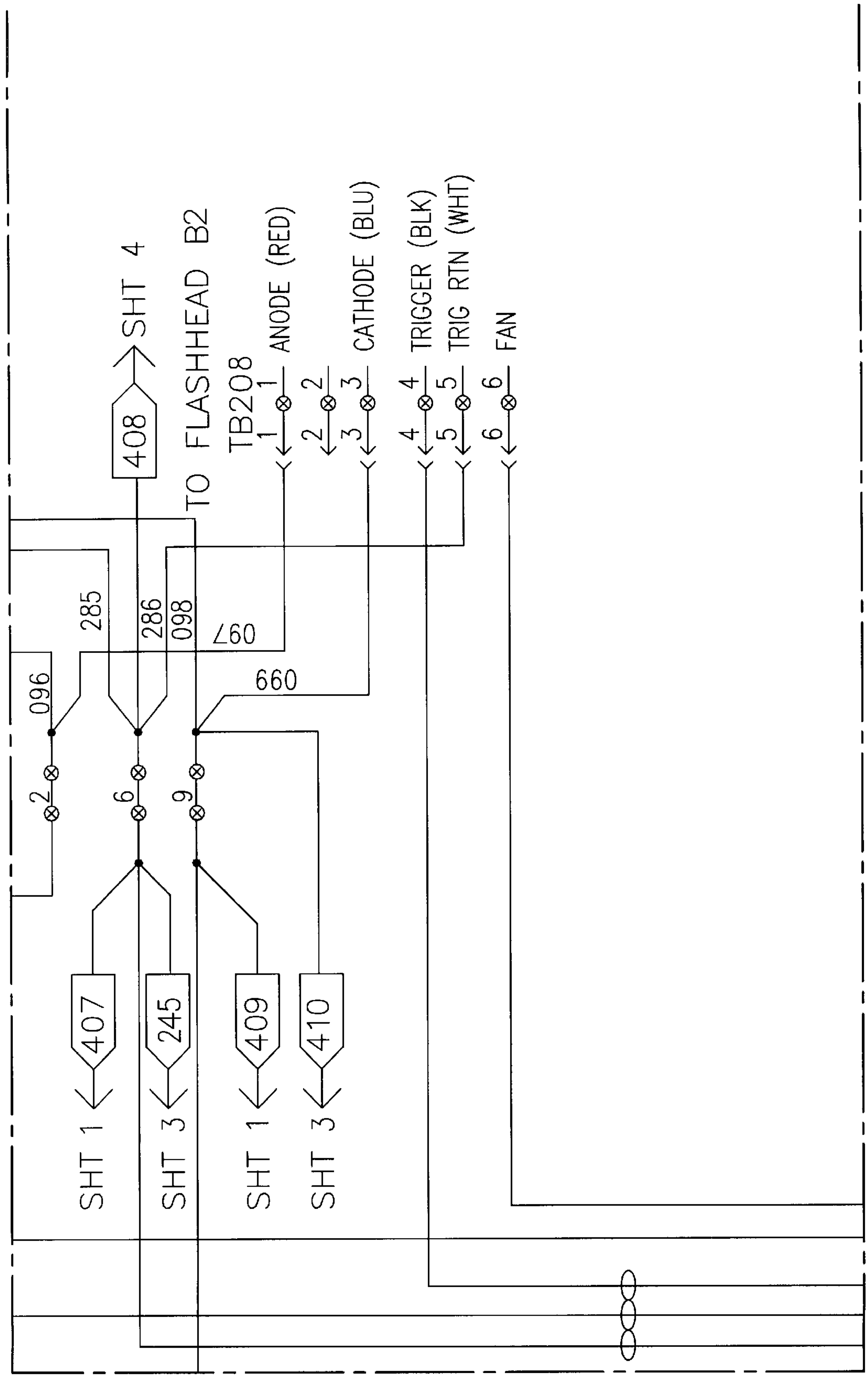

294
594
092
595
L22
K22
K21
592
593
021
218
219
091
020
SHT 1
PCB1, J2
PCB1, J2
089
G10
PCB1, J6
PCB1, J15
082
083
084
G10
087

FIG. 2b5



408
SHT 4
TO FLASHHEAD B2
TB208
1 ANODE (RED)
2
3 CATHODE (BLU)
4 TRIGGER (BLK)
5 TRIG RTN (WHT)
6 FAN
285
286
098
097
096
660
2
6
9
407
245
409
410
SHT 1
SHT 3
SHT 1
SHT 3

FIG. 2b6

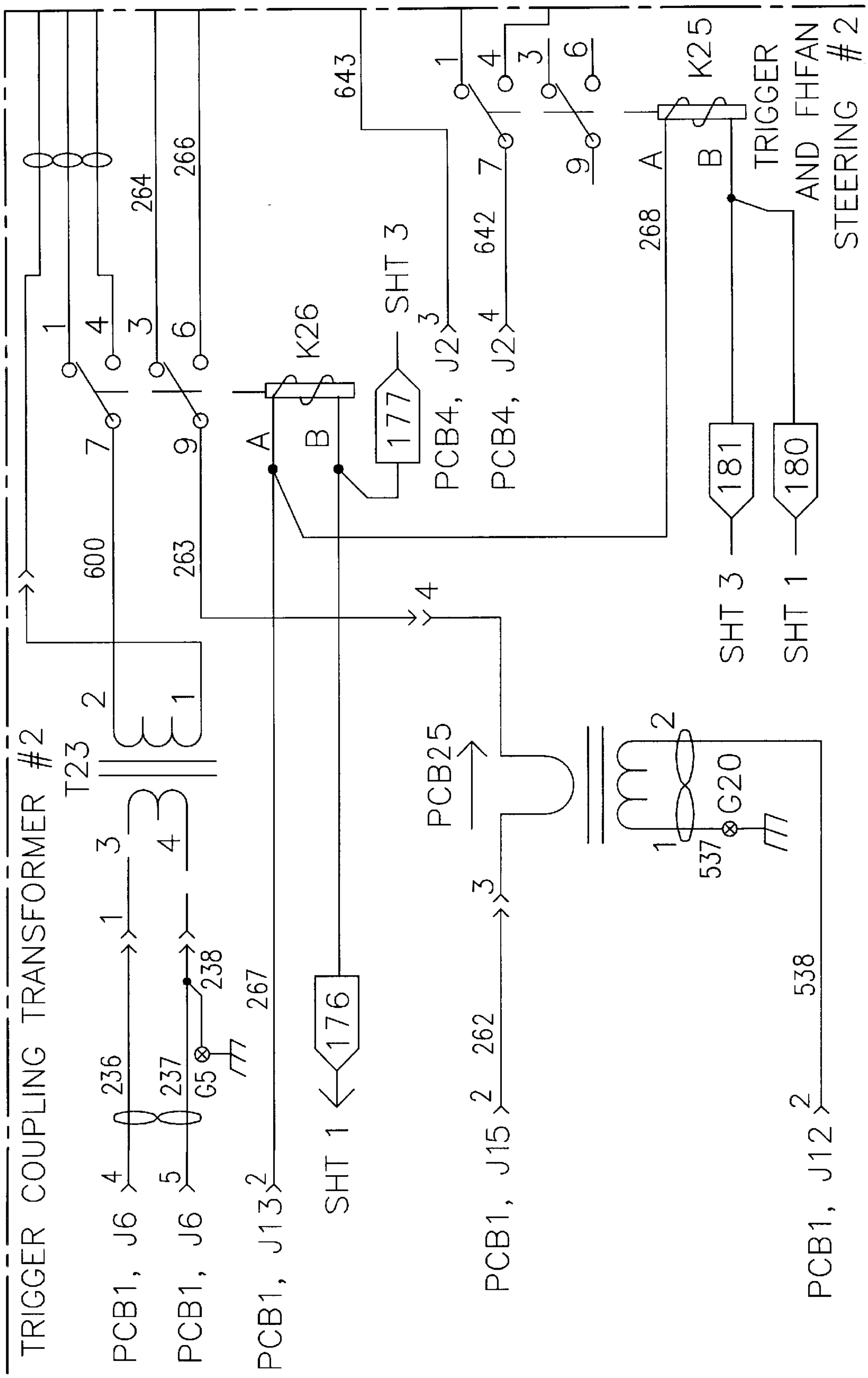
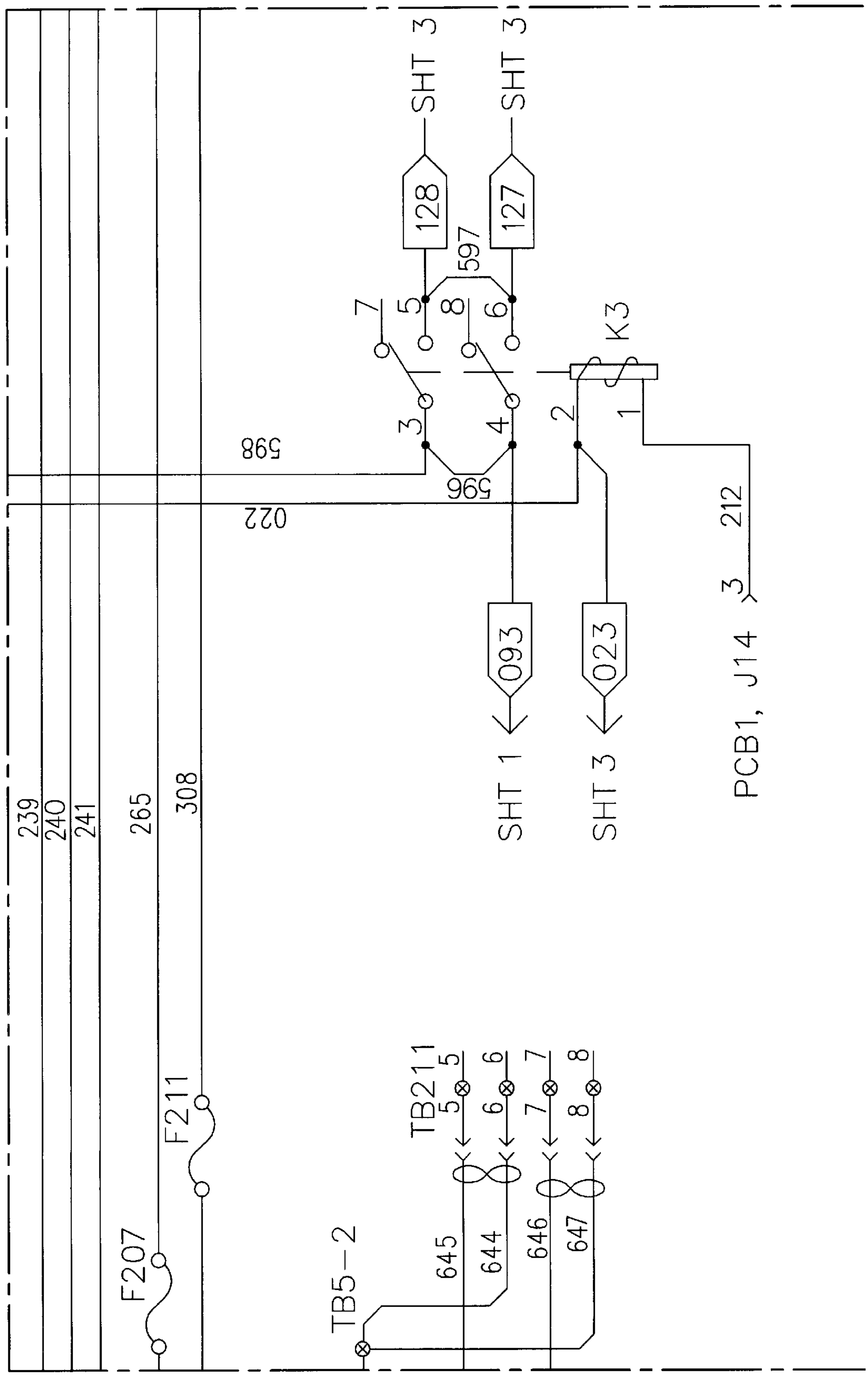

TRIGGER COUPLING TRANSFORMER #2
T23
K26
K25
TRIGGER AND FHFAN STEERING #2
PCB1, J6
PCB1, J6
PCB1, J13
PCB1, J15
PCB1, J12
PCB4, J2
PCB4, J2
PCB25
SHT 1
SHT 3
SHT 3
SHT 1
G5
G20
176
177
180
181
236
237
238
267
262
538
537
600
263
264
266
643
642
268

FIG. 2b7



SHT 3
SHT 3
128
127
597
7
5
8
6
K3
3
4
2
1
598
596
022
212
093
023
SHT 1
SHT 3
PCB1, J14
239
240
241
265
308
F207
F211
TB5-2
TB211
645
644
646
647

FIG. 2b8

FIG. 2b9

FIG. 2c1	FIG. 2c2	FIG. 2c3
FIG. 2c4	FIG. 2c5	FIG. 2c6
FIG. 2c7	FIG. 2c8	FIG. 2c9

FIG. 2c

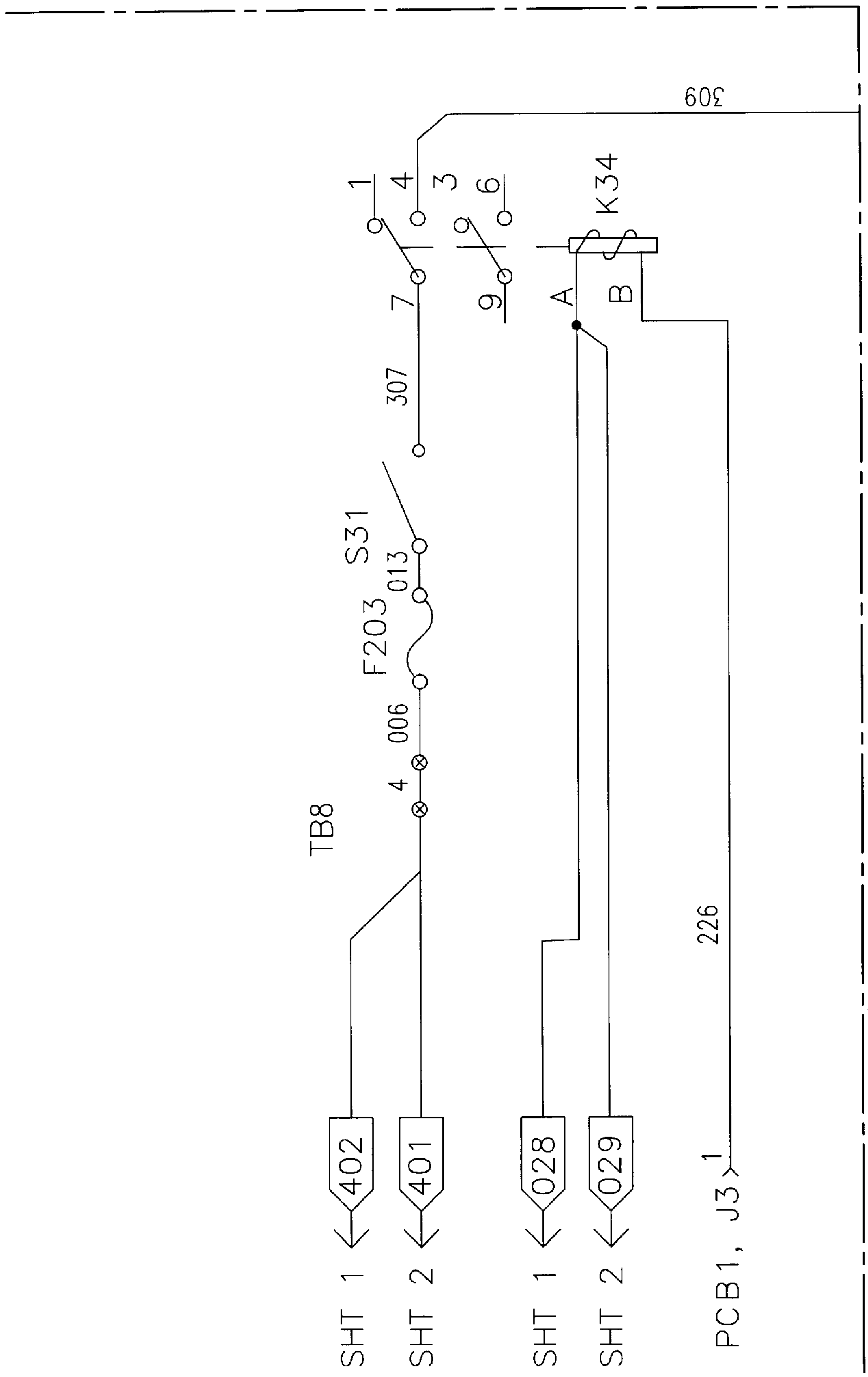

309
K34
1
4
3
6
7
9
A
B
307
S31
013
F203
006
4
TB8
226
402
401
028
029
SHT 1
SHT 2
SHT 1
SHT 2
PCB1, J3
1

FIG. 2c1

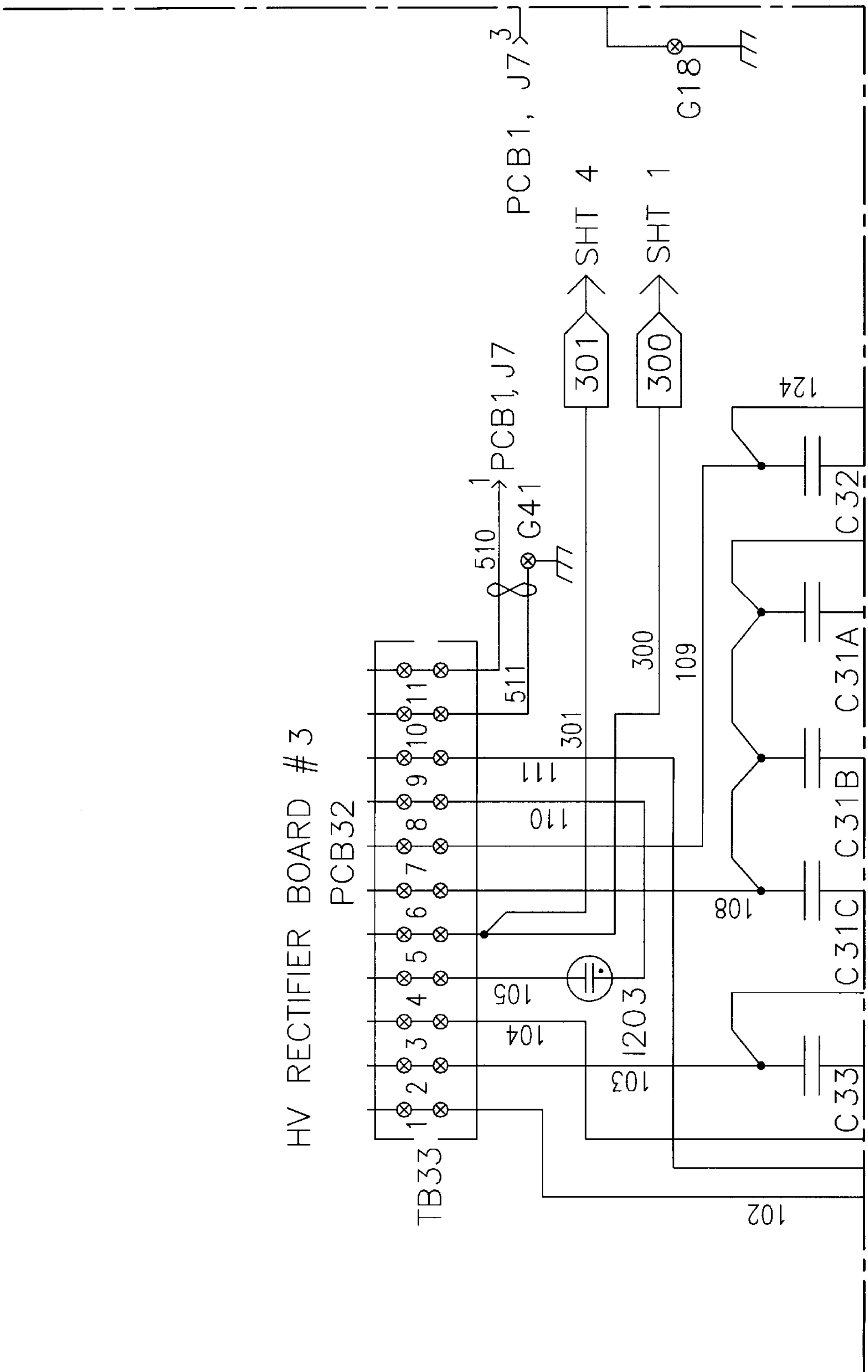

HV RECTIFIER BOARD #3
PCB32
TB33
PCB1, J7
PCB1, J7
SHT 4
SHT 1
301
300
G18
G41
510
511
301
300
109
111
110
108
105
104
103
102
124
1203
C32
C31A
C31B
C31C
C33

FIG. 2c2

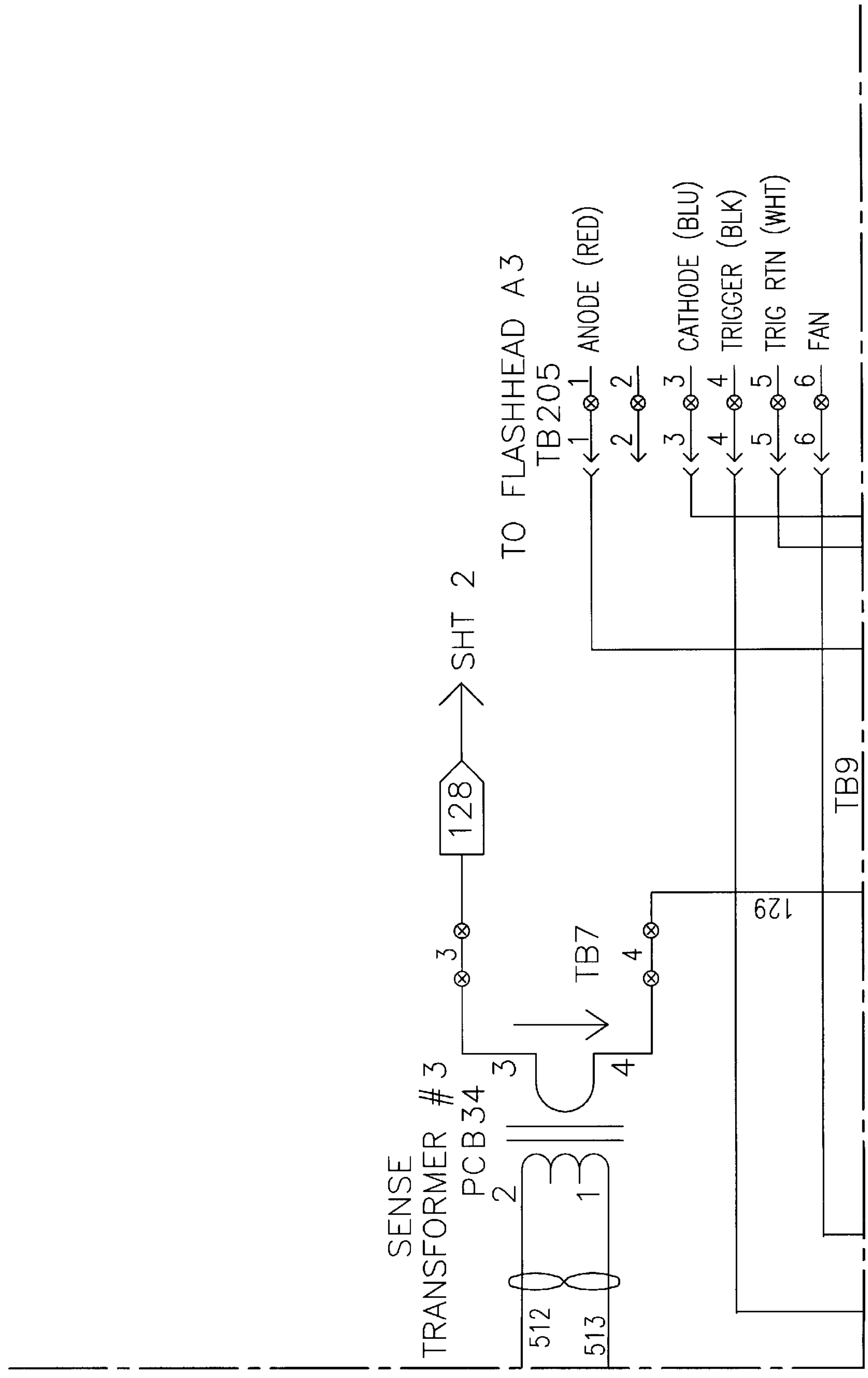

SENSE TRANSFORMER # 3
PCB34
512
513
TB7
128
SHT 2
129
TB9
TO FLASHHEAD A 3
TB205
ANODE (RED)
CATHODE (BLU)
TRIGGER (BLK)
TRIG RTN (WHT)
FAN

FIG. 2c3

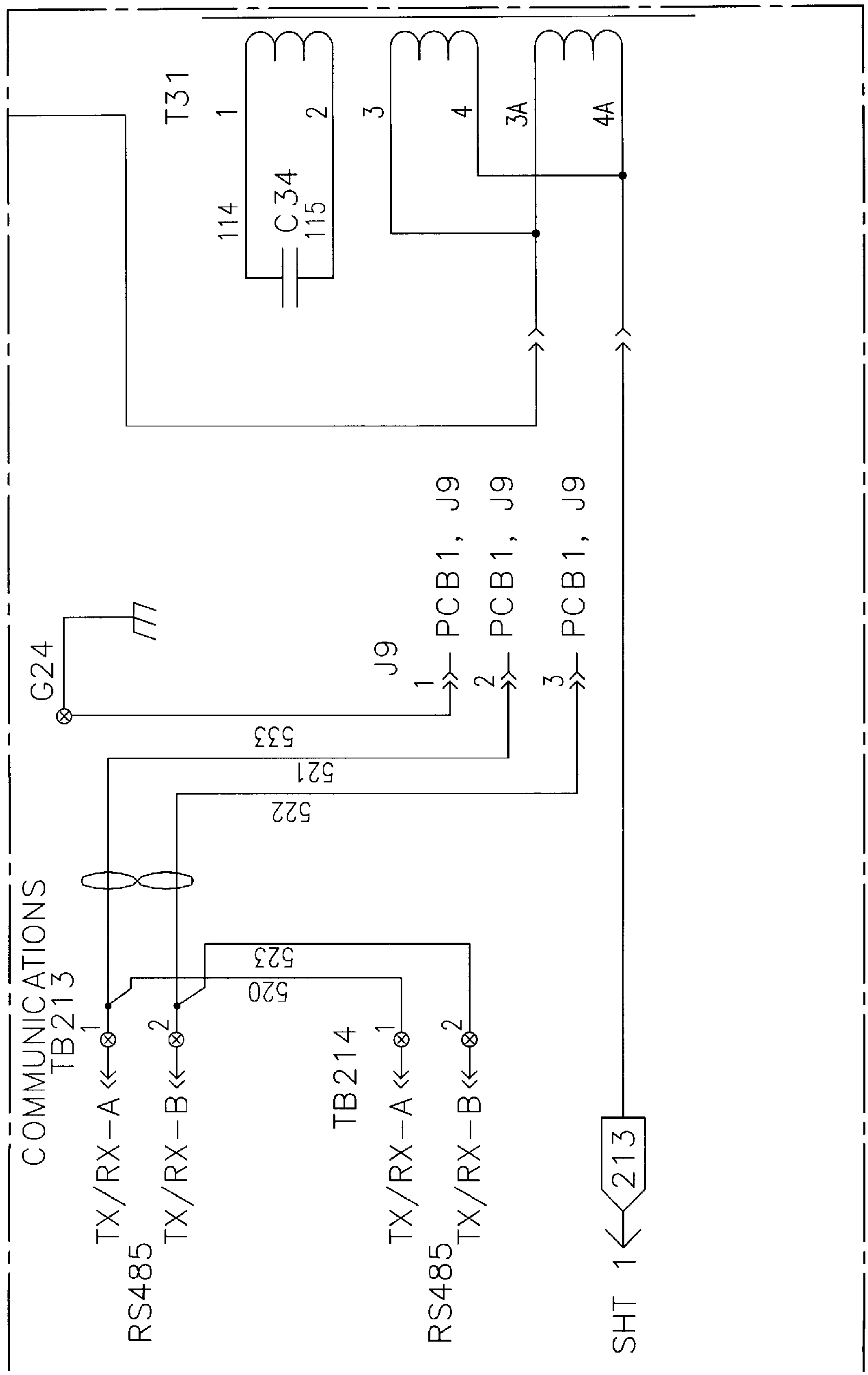

T31
1
2
3
4
3A
4A
114
C34
115
G24
J9
1
2
3
PCB1, J9
PCB1, J9
PCB1, J9
533
521
522
COMMUNICATIONS
TB213
1
2
523
520
TB214
1
2
TX/RX–A
TX/RX–B
TX/RX–A
TX/RX–B
RS485
RS485
213
SHT 1

FIG. 2c4

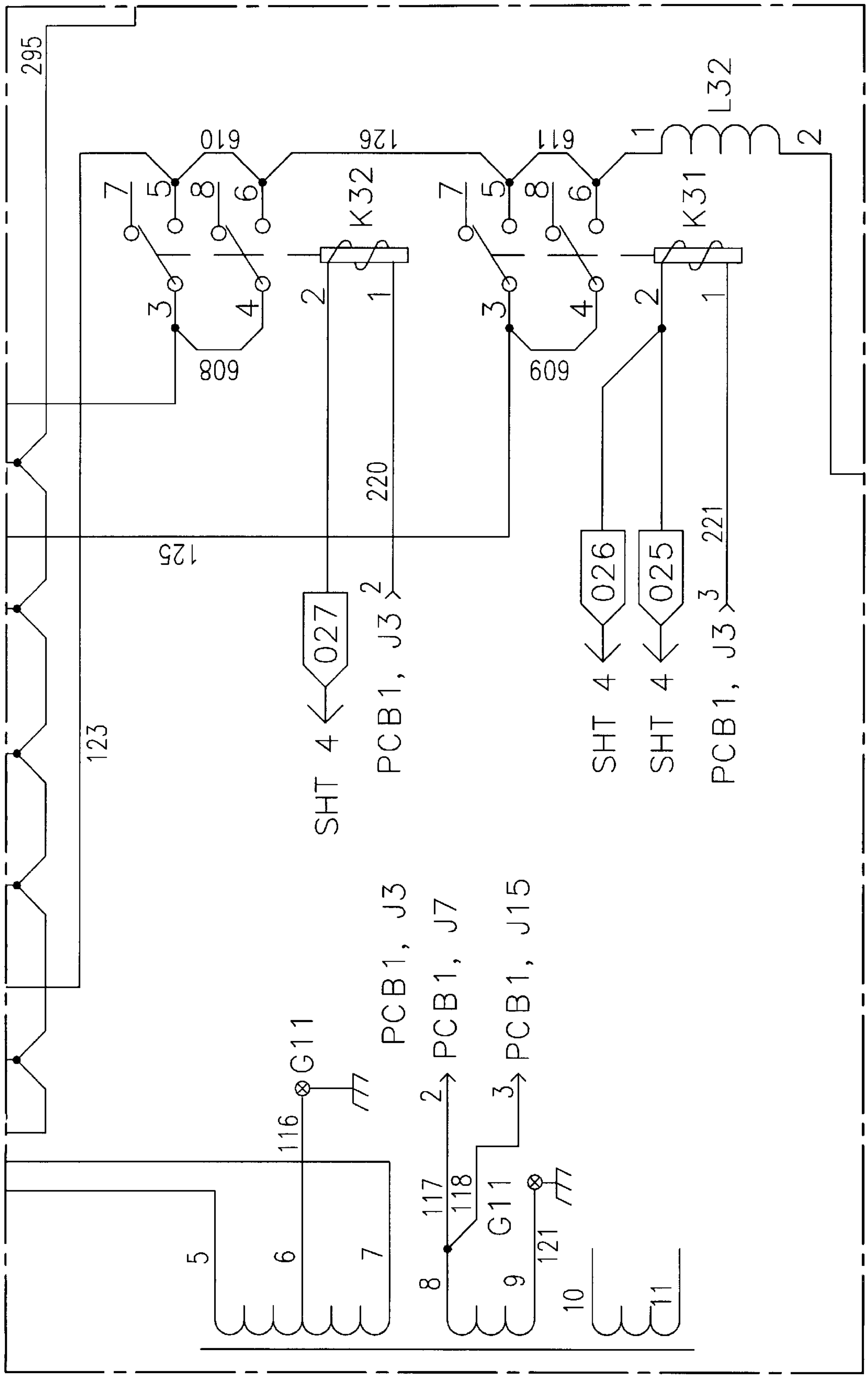

295
610
126
611
L32
K32
K31
608
609
220
125
221
027
026
025
SHT 4
PCB1, J3
123
PCB1, J7
PCB1, J15
G11
116
117
118
121

FIG. 2c5

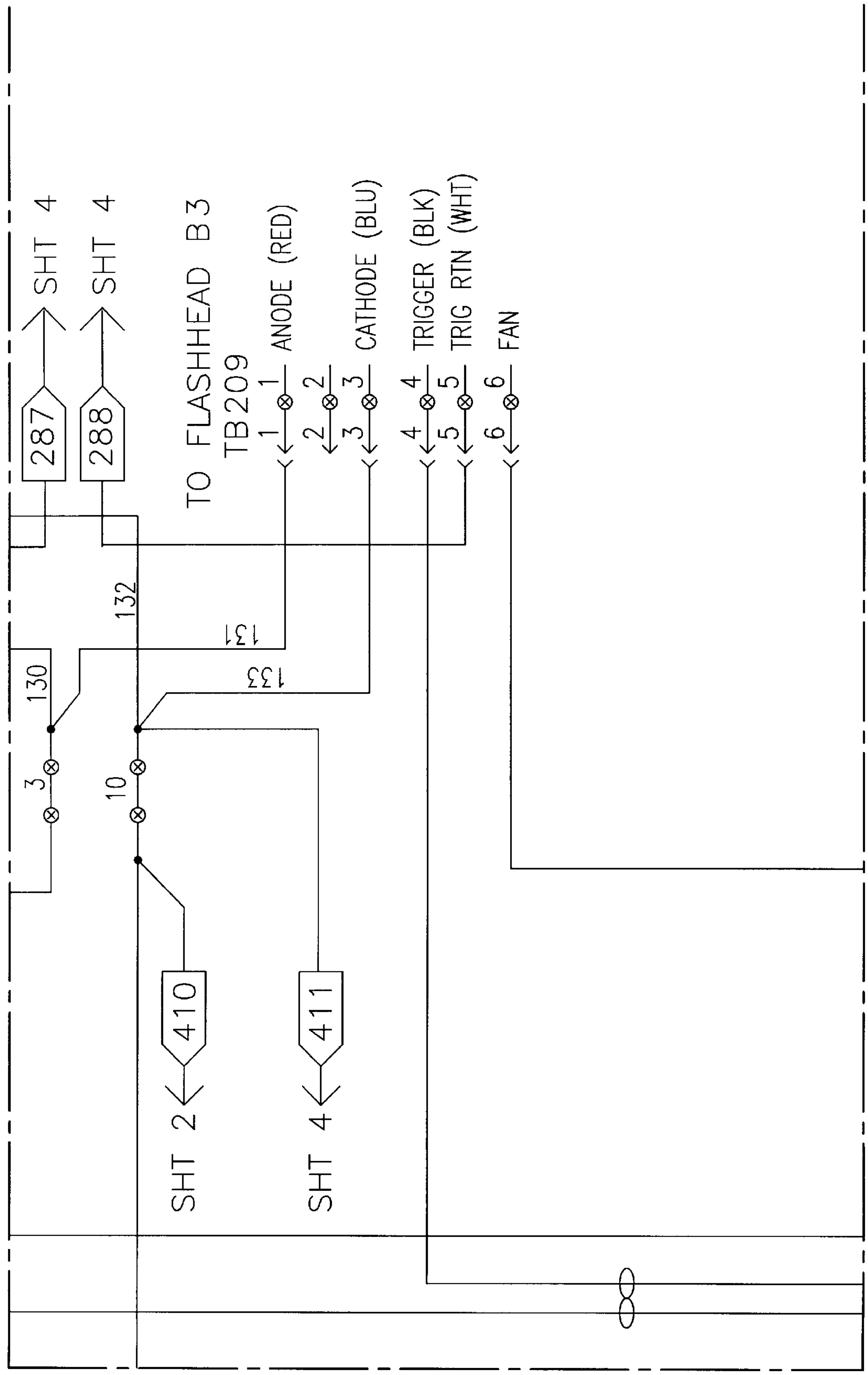

SHT 4
SHT 4
287
288
TO FLASHHEAD B3
TB209
1 ANODE (RED)
2
3 CATHODE (BLU)
4 TRIGGER (BLK)
5 TRIG RTN (WHT)
6 FAN
132
131
130
133
3
10
410
411
SHT 2
SHT 4

FIG. 2c6

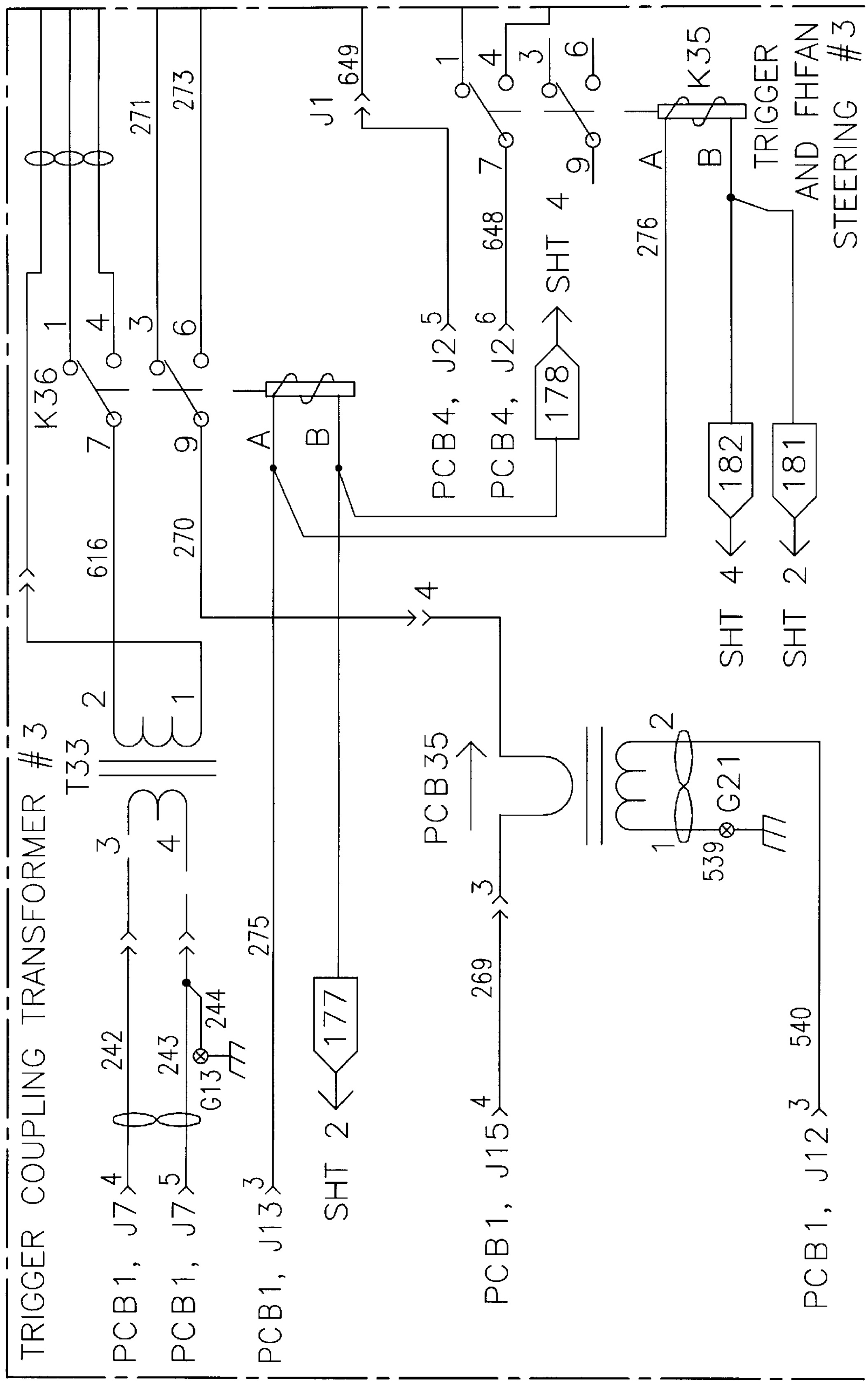

TRIGGER COUPLING TRANSFORMER #3
TRIGGER AND FHFAN STEERING #3
K36
K35
T33
G13
G21
PCB1, J7
PCB1, J7
PCB1, J13
PCB1, J15
PCB1, J12
PCB4, J2
PCB4, J2
PCB35
J1
SHT 2
SHT 4
SHT 4
SHT 2
177
178
182
181
242
243
244
275
269
540
539
616
270
271
273
649
648
276

FIG. 2c7

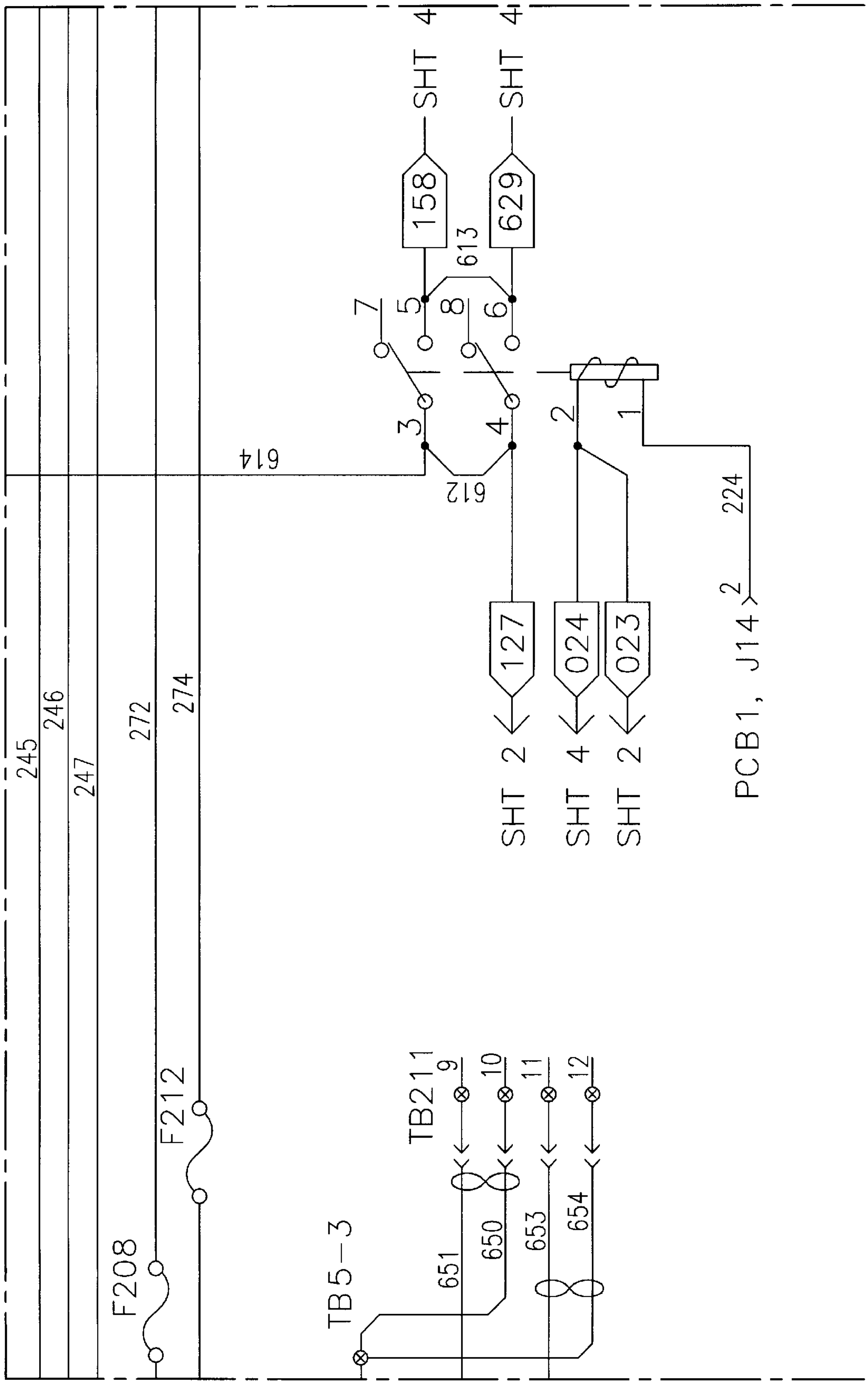

245
246
247
272
274
F208
F212
614
612
613
3
4
5
6
7
8
2
1
158
629
SHT 4
SHT 4
127
024
023
SHT 2
SHT 4
SHT 2
224
PCB1, J14
2
TB5-3
TB211
9
10
11
12
651
650
653
654

FIG. 2c8

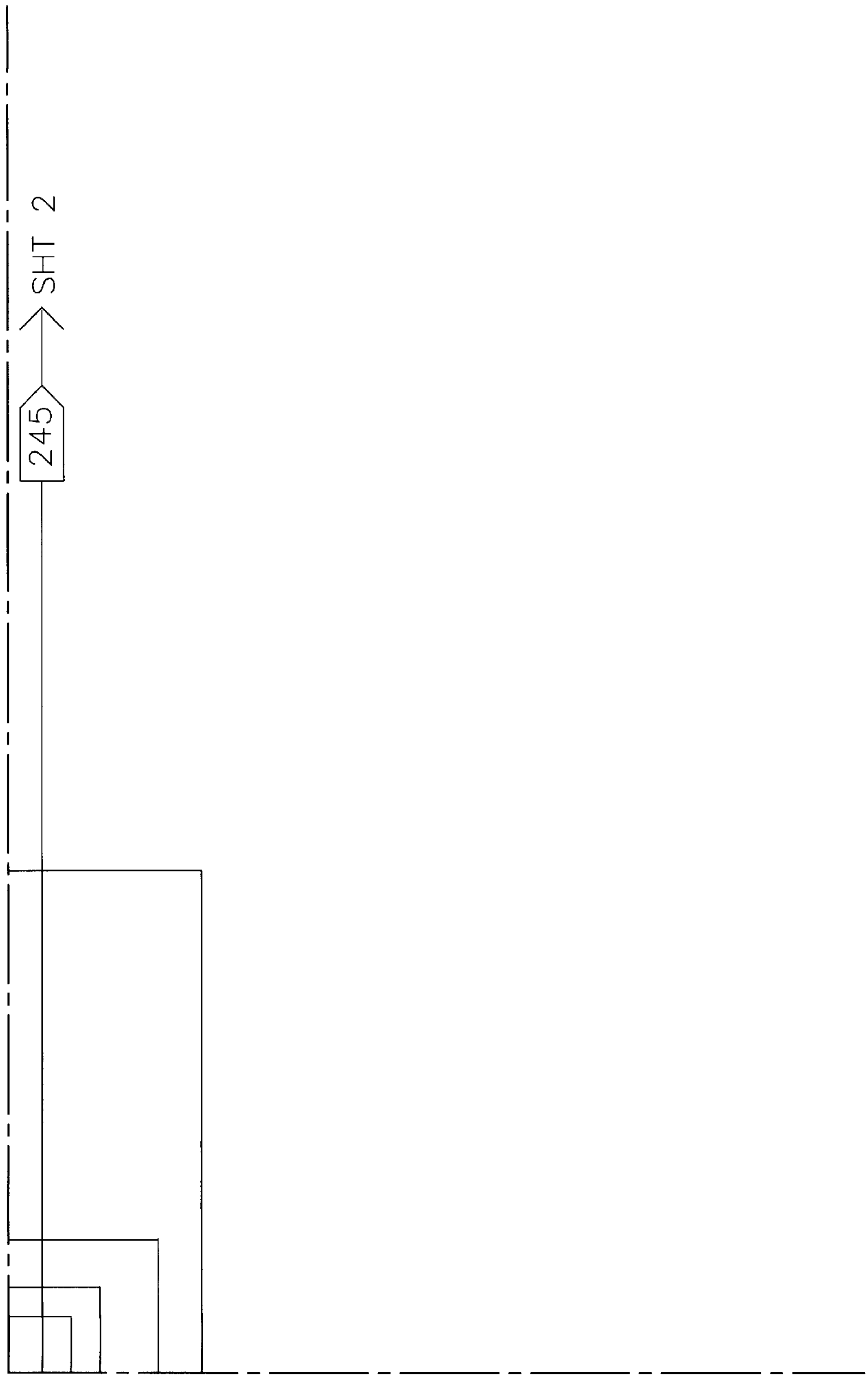
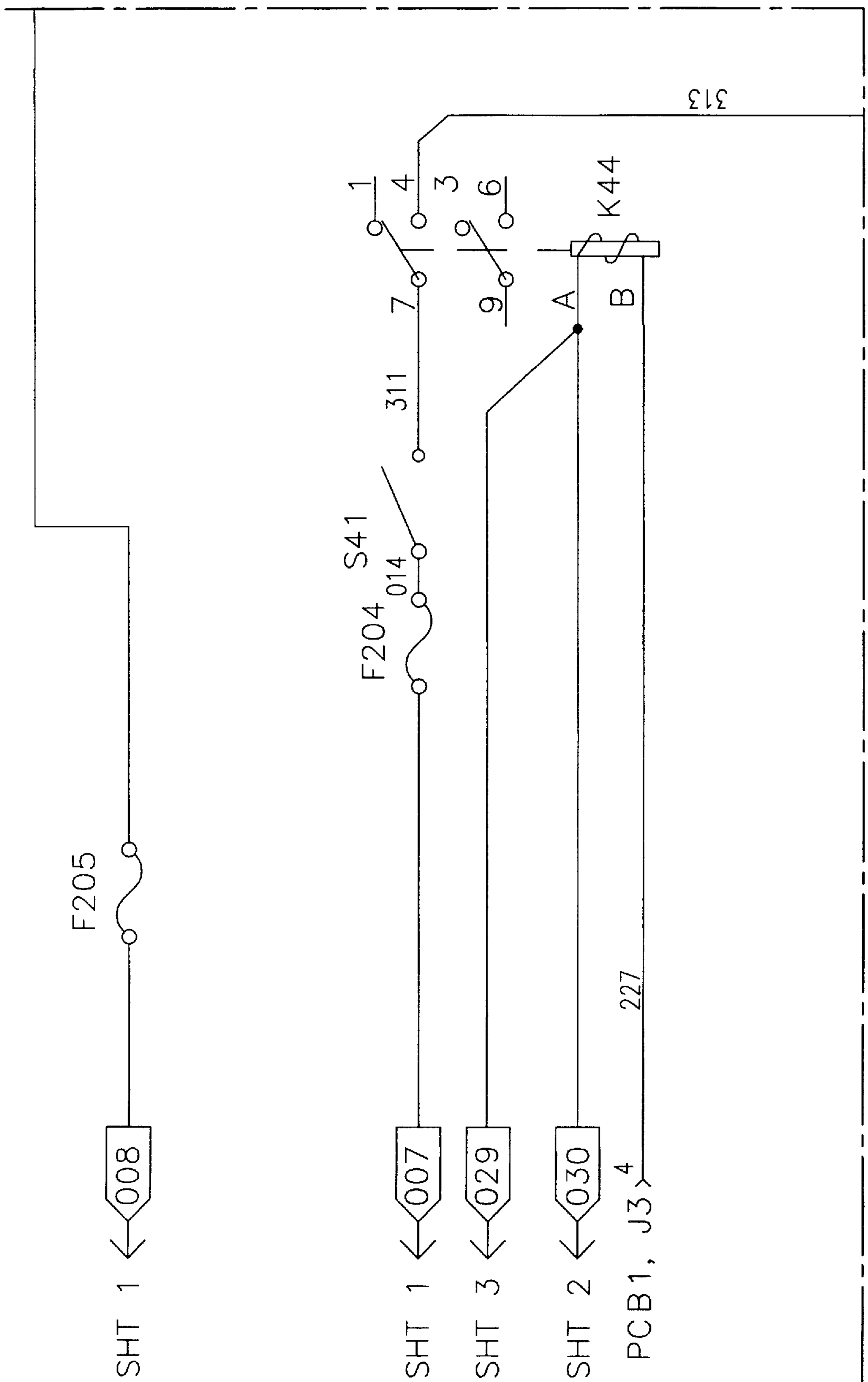


FIG. 2c9

FIG. 2d1	FIG. 2d2	FIG. 2d3
FIG. 2d4	FIG. 2d5	FIG. 2d6
FIG. 2d7	FIG. 2d8	FIG. 2d9

FIG. 2d



313
1
4
3
6
K44
7
9
9
A
B
311
S41
014
F204
F205
227
008
007
029
030
4
SHT 1
SHT 1
SHT 3
SHT 2
PCB1, J3

FIG. 2d1

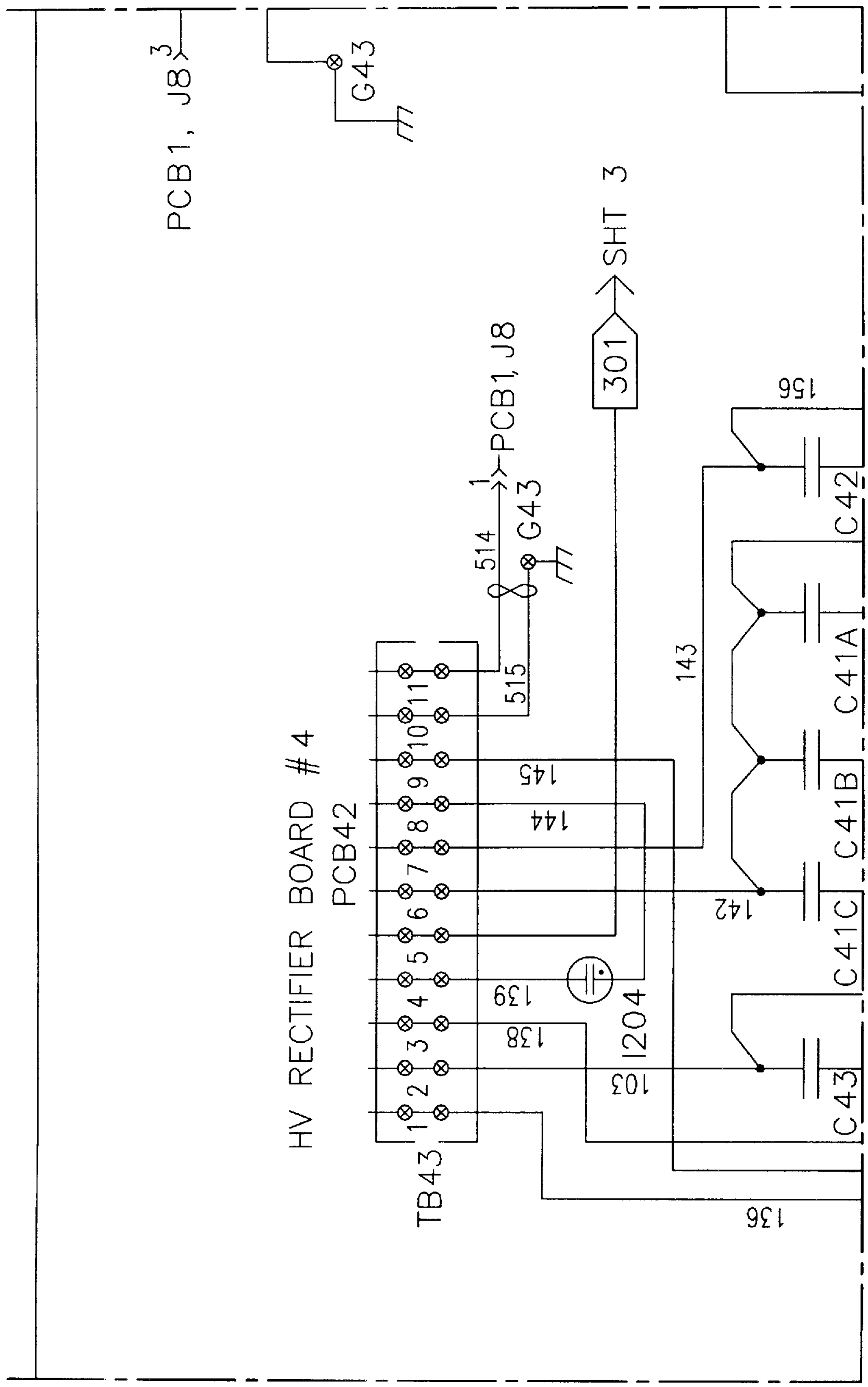

PCB1, J8
3
G43
SHT 3
301
PCB1, J8
1
514
G43
515
HV RECTIFIER BOARD #4
PCB42
TB43
1
2
3
4
5
6
7
8
9
10
11
145
144
143
142
139
138
103
136
156
I204
C42
C41A
C41B
C41C
C43

FIG. 2d2

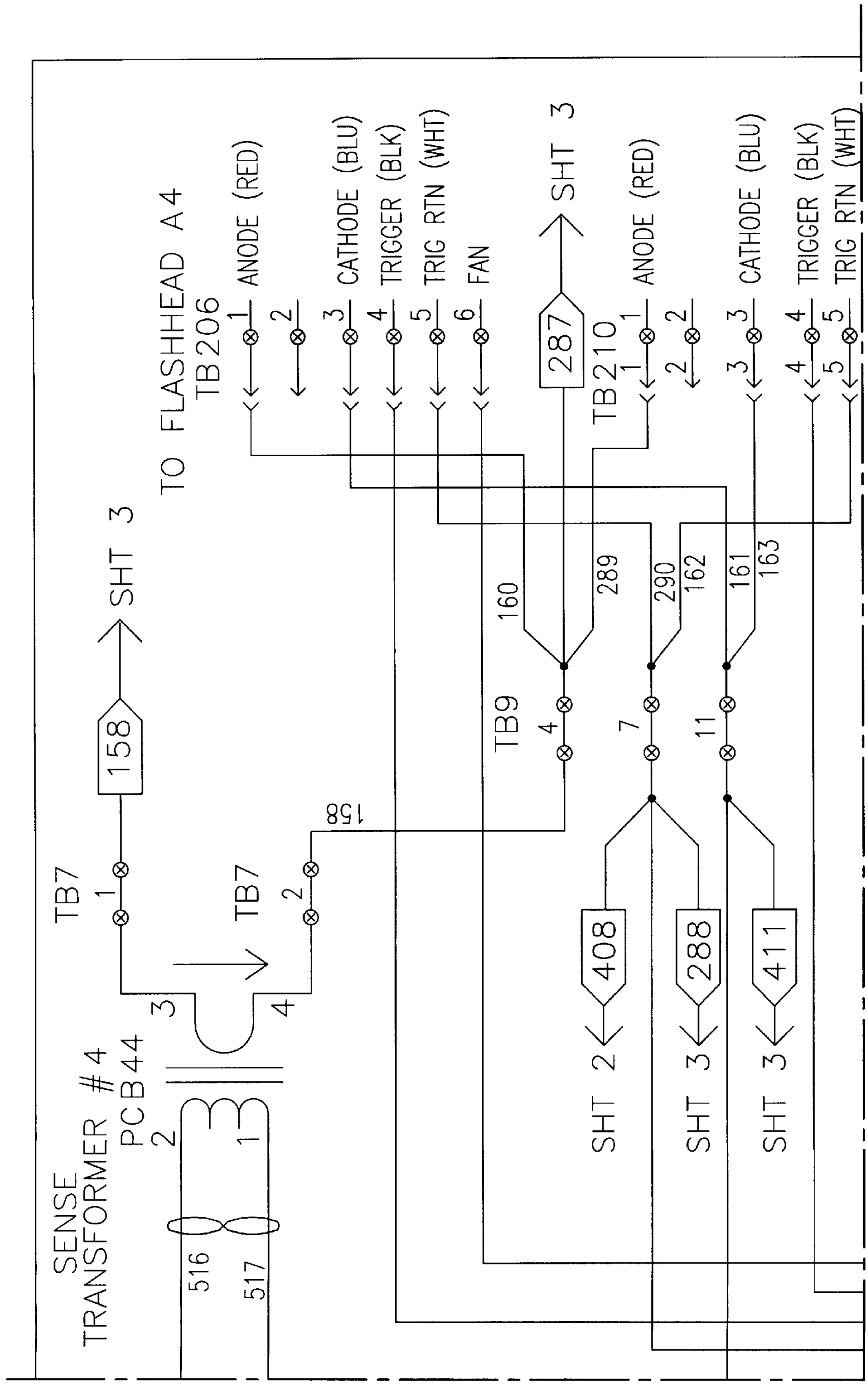

SENSE TRANSFORMER #4
PCB44
516
517
TB7
158
SHT 3
TO FLASHHEAD A4
TB206
ANODE (RED)
CATHODE (BLU)
TRIGGER (BLK)
TRIG RTN (WHT)
FAN
287
TB210
TB9
160
289
290
162
161
163
408
288
411
SHT 2

FIG. 2d3

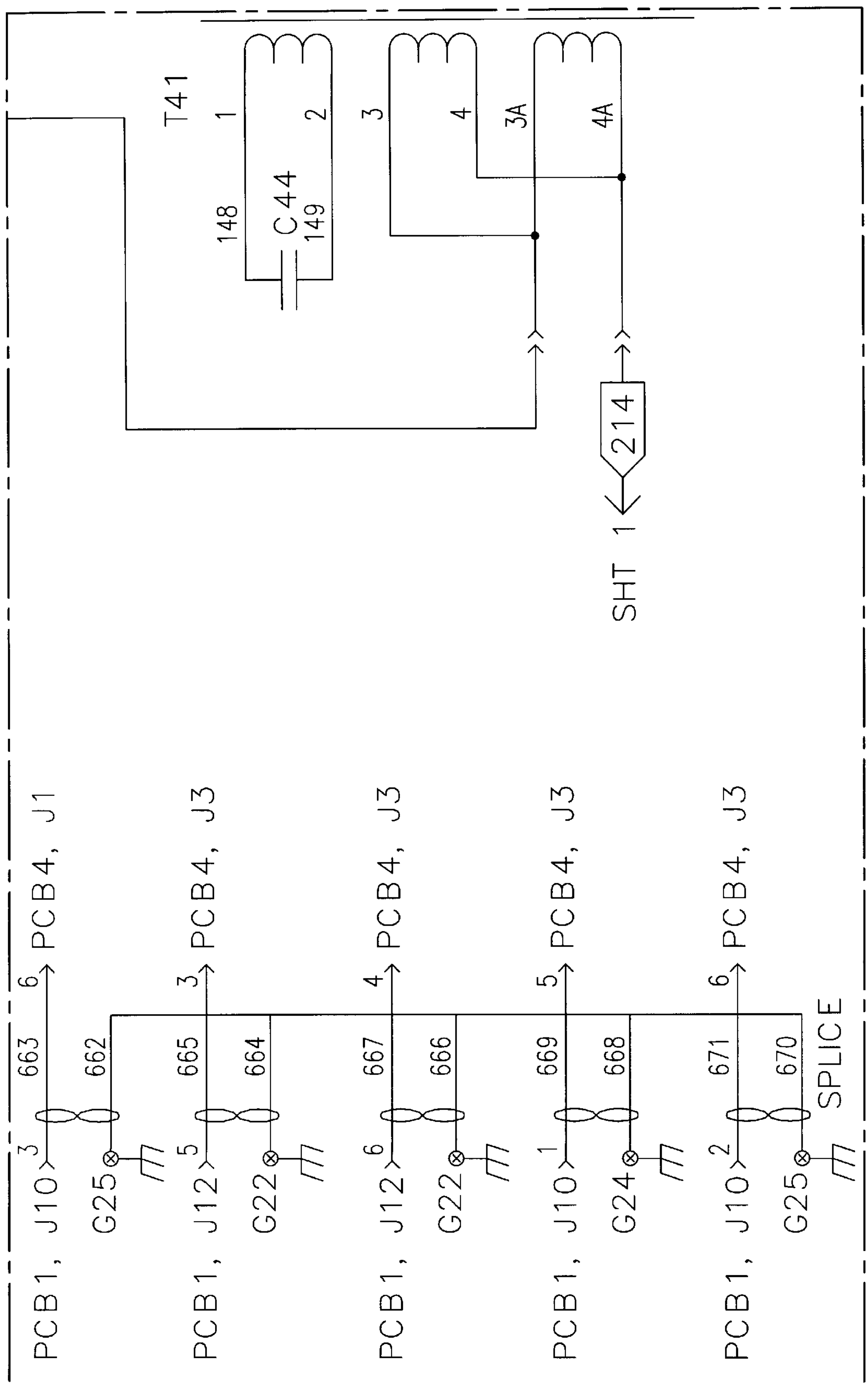

T41
1
2
3
4
3A
4A
148
C44
149
214
SHT 1
PCB1, J10 3 663 6 PCB4, J1
G25 662
PCB1, J12 5 665 3 PCB4, J3
G22 664
PCB1, J12 6 667 4 PCB4, J3
G22 666
PCB1, J10 1 669 5 PCB4, J3
G24 668
PCB1, J10 2 671 6 PCB4, J3
G25 670
SPLICE

FIG. 2d4

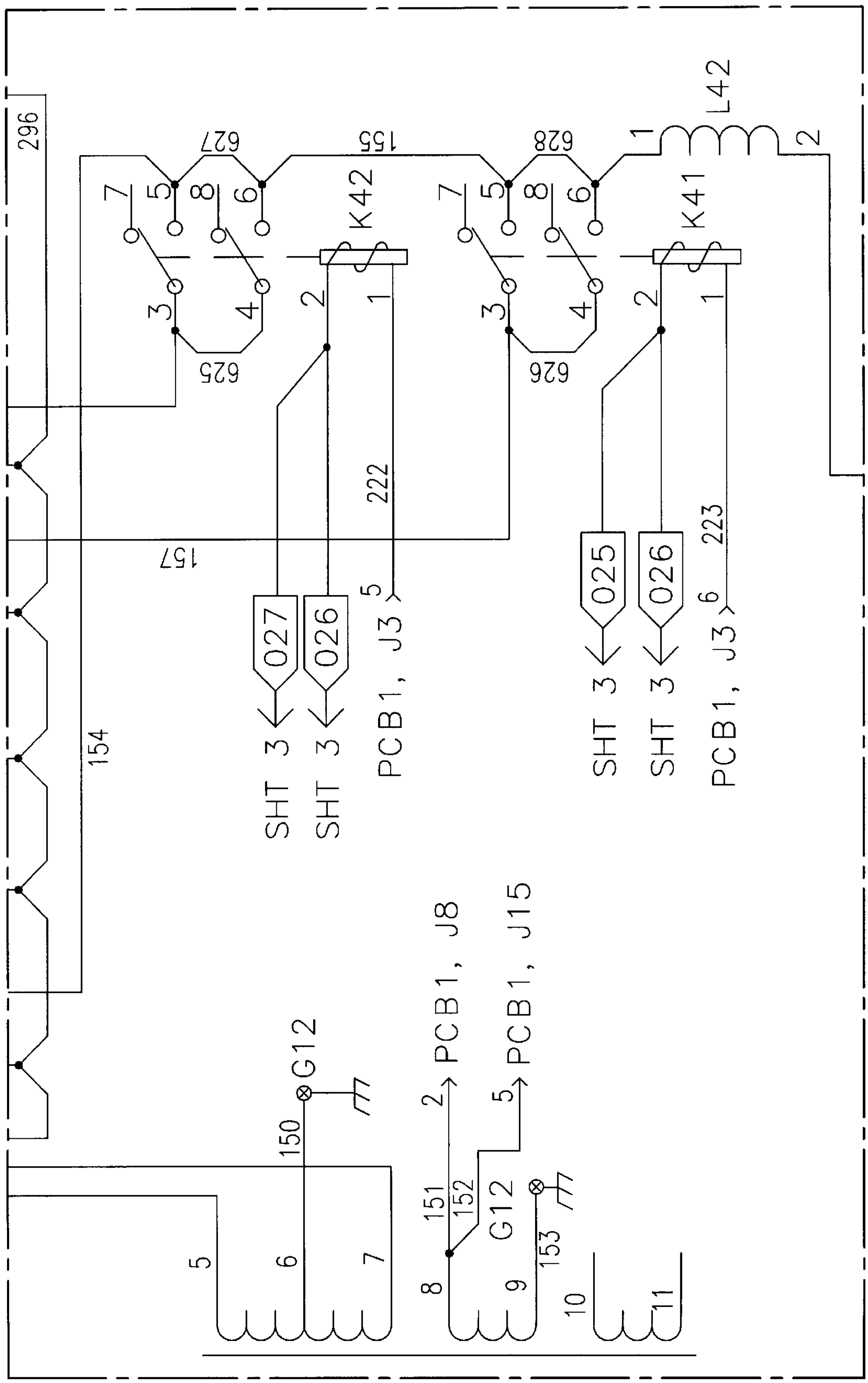

296
627
155
628
L42
K42
K41
625
626
222
223
157
154
027
026
025
SHT 3
SHT 3
SHT 3
SHT 3
PCB1, J3
PCB1, J3
PCB1, J8
PCB1, J15
G12
G12
150
151
152
153

FIG. 2d5

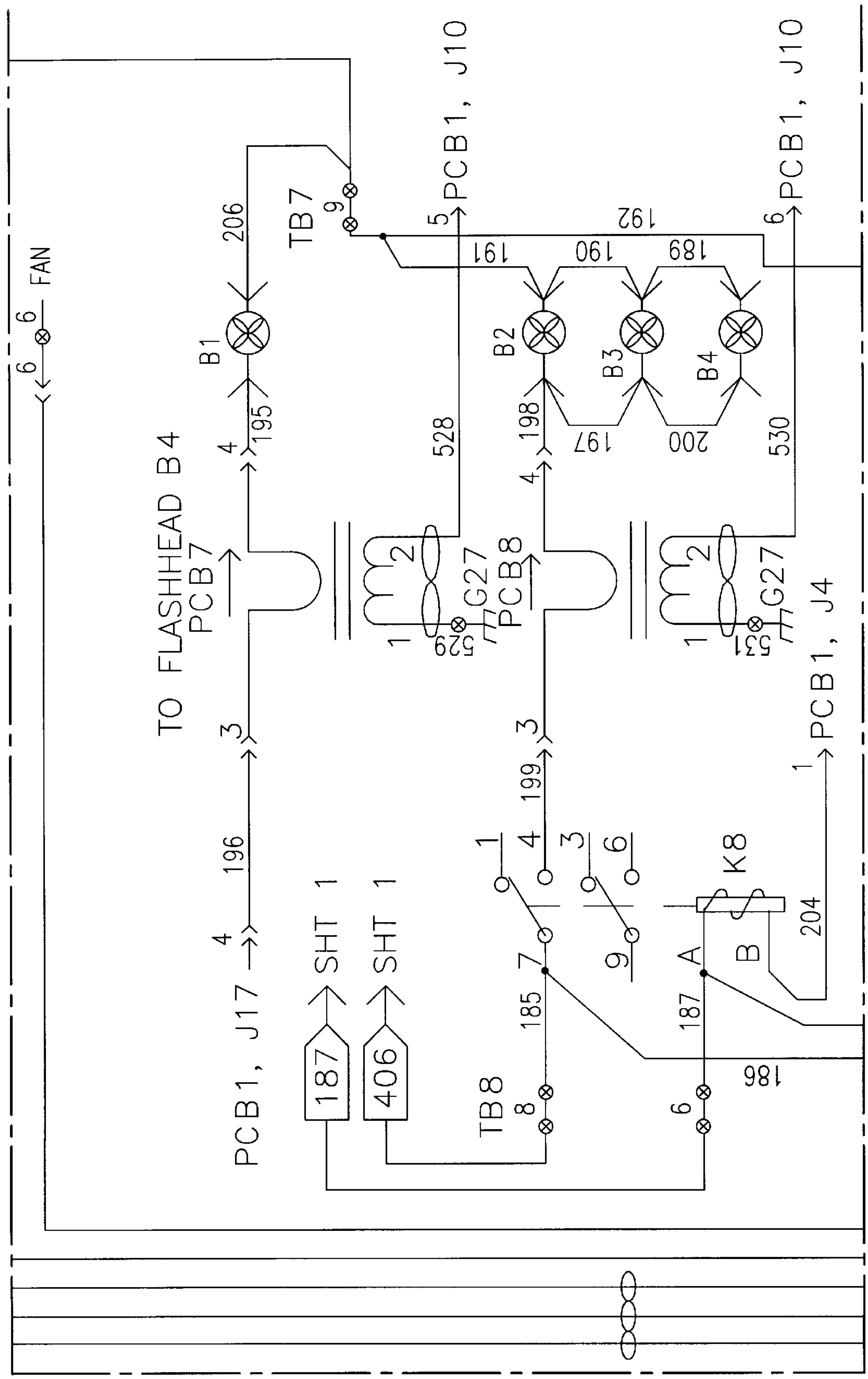

FAN
PCB1, J10
TB7
B1
B2
B3
B4
TO FLASHHEAD B4
PCB7
PCB8
G27
K8
TB8
SHT 1
PCB1, J17
PCB1, J4
187
406

FIG. 2d6

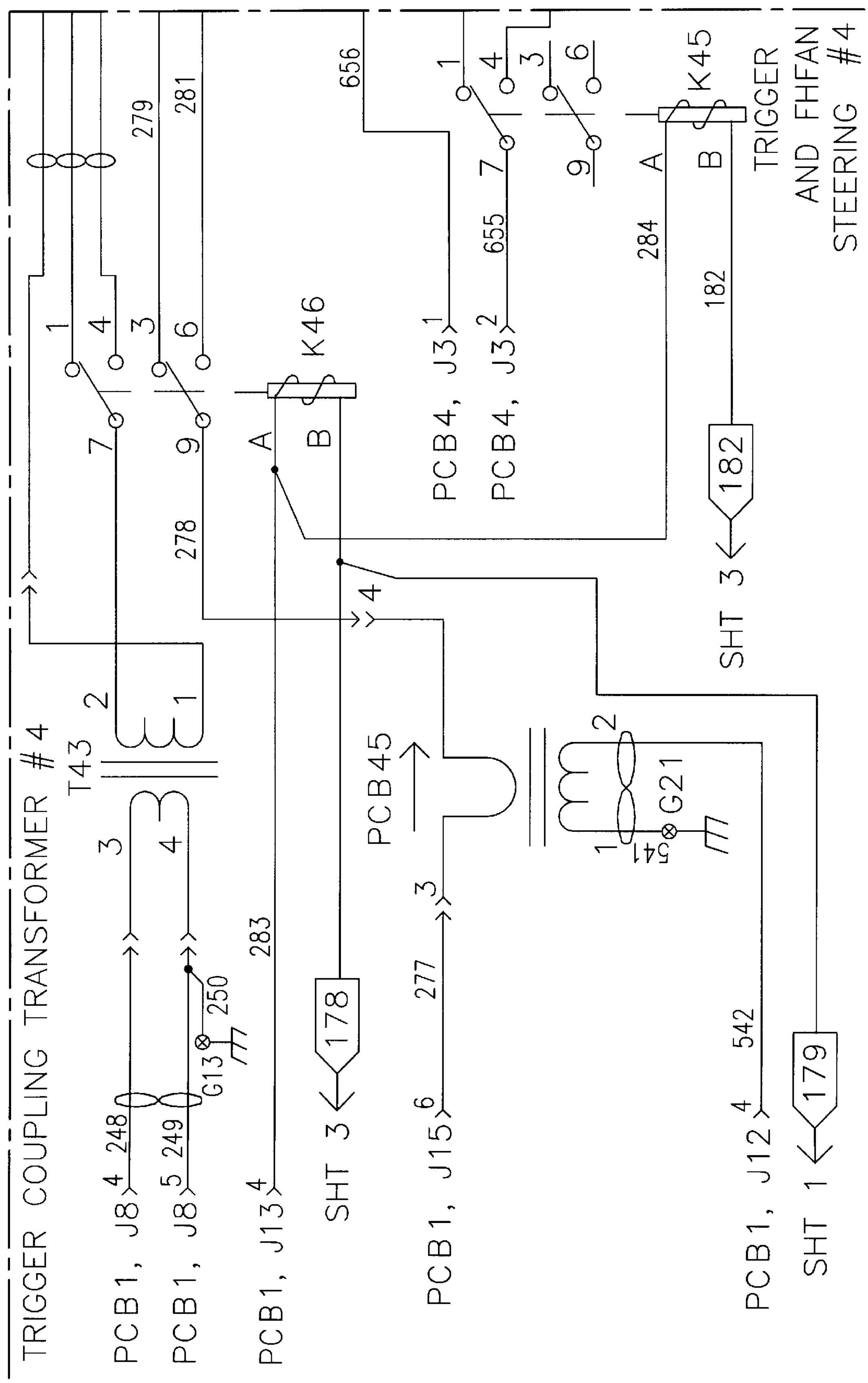
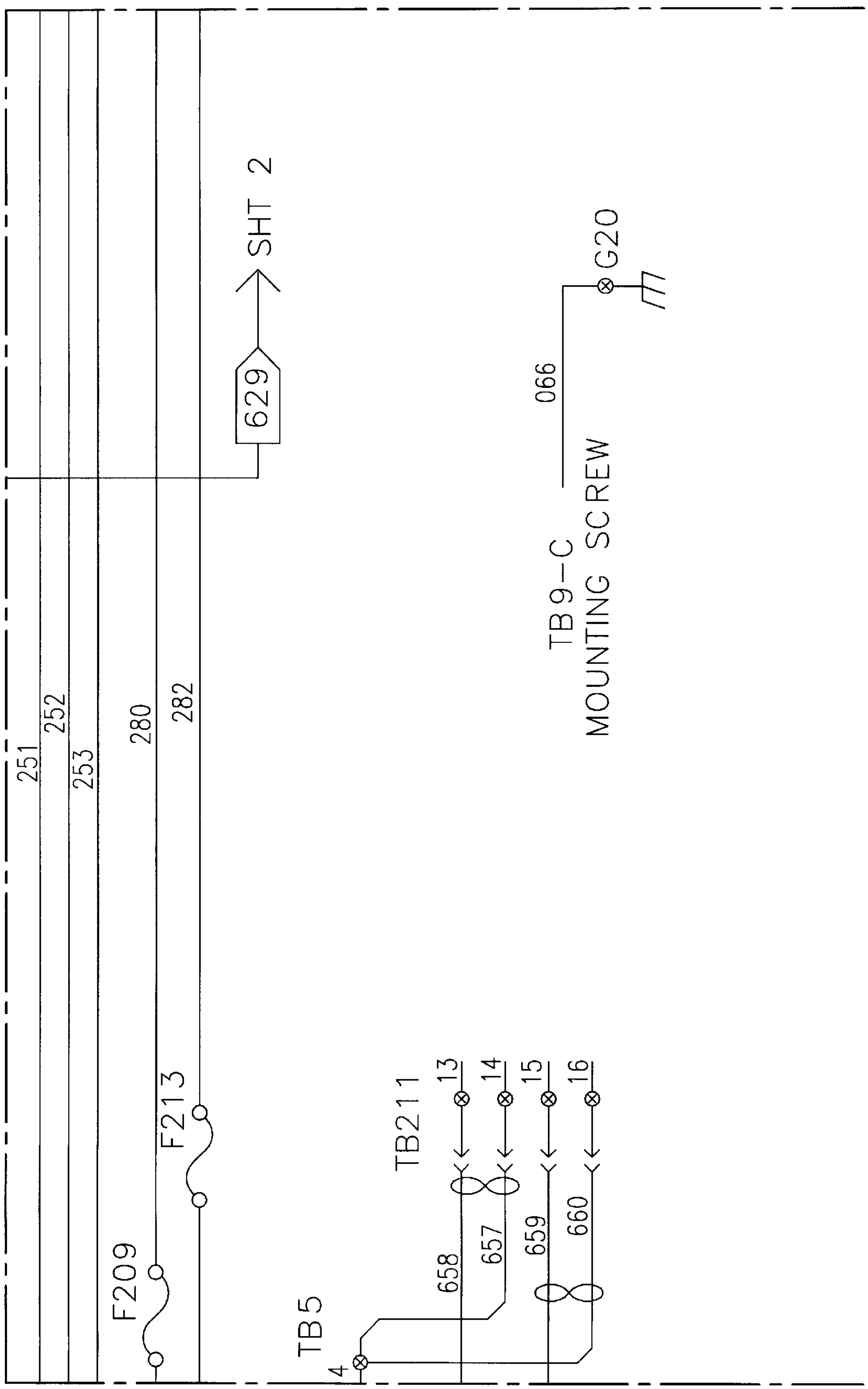

TRIGGER COUPLING TRANSFORMER #4
TRIGGER AND FHFAN STEERING #4
T43
K46
K45
G13
G21
PCB1, J8 4
PCB1, J8 5
PCB1, J13 4
PCB1, J15 6
PCB1, J12 4
PCB4, J3 1
PCB4, J3 2
PCB45
248
249
250
283
277
542
278
279
281
656
655
284
182
541
178
179
SHT 3
SHT 1

FIG. 2d7



629
SHT 2
G20
066
TB9-C
MOUNTING SCREW
251
252
253
280
282
F213
F209
TB211
13
14
15
16
658
657
659
660
TB5
4

FIG. 2d8

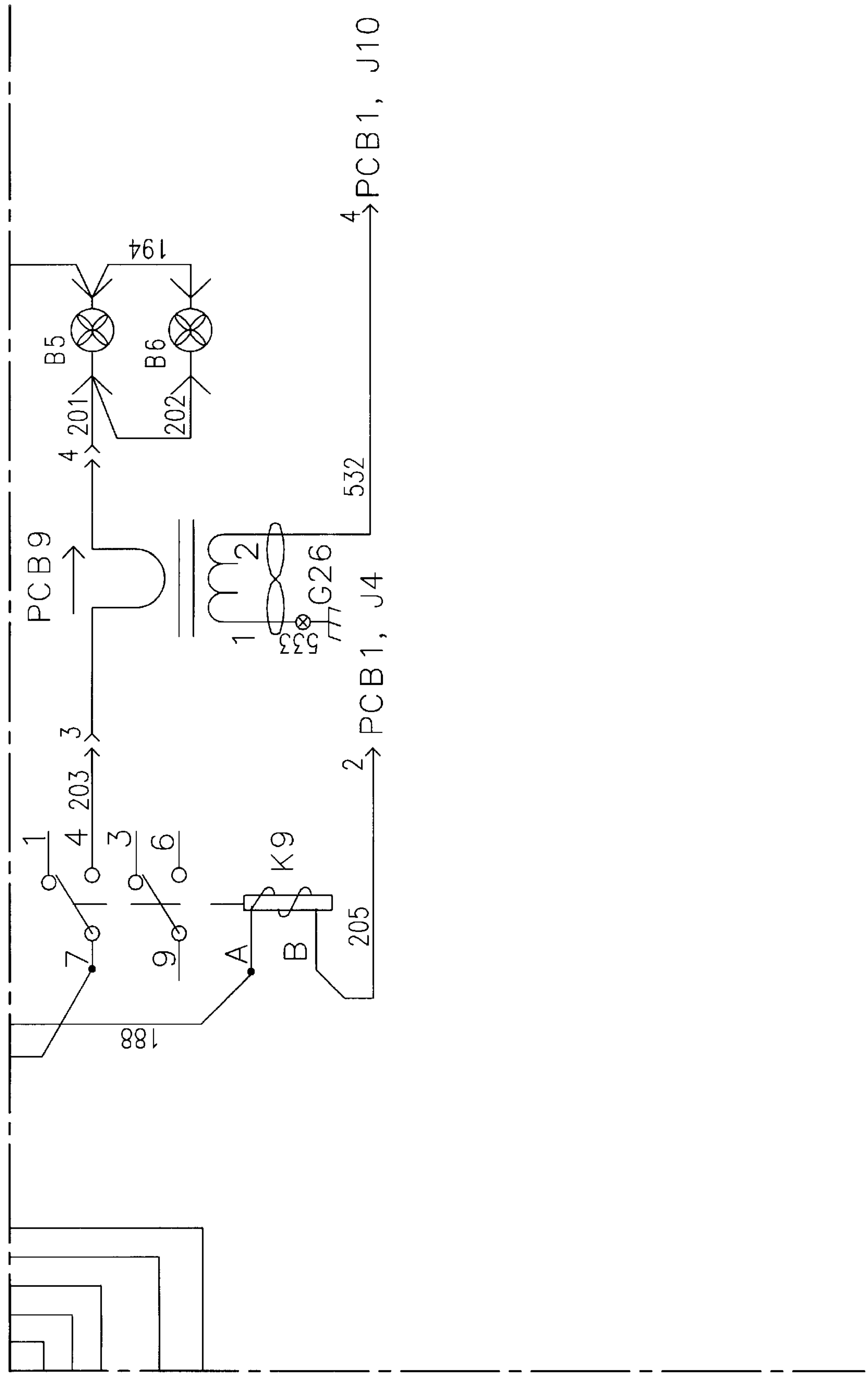

PCB1, J10
194
B5
B6
201
202
PCB9
532
G26
533
PCB1, J4
203
K9
A
B
205
188

FIG. 2d9

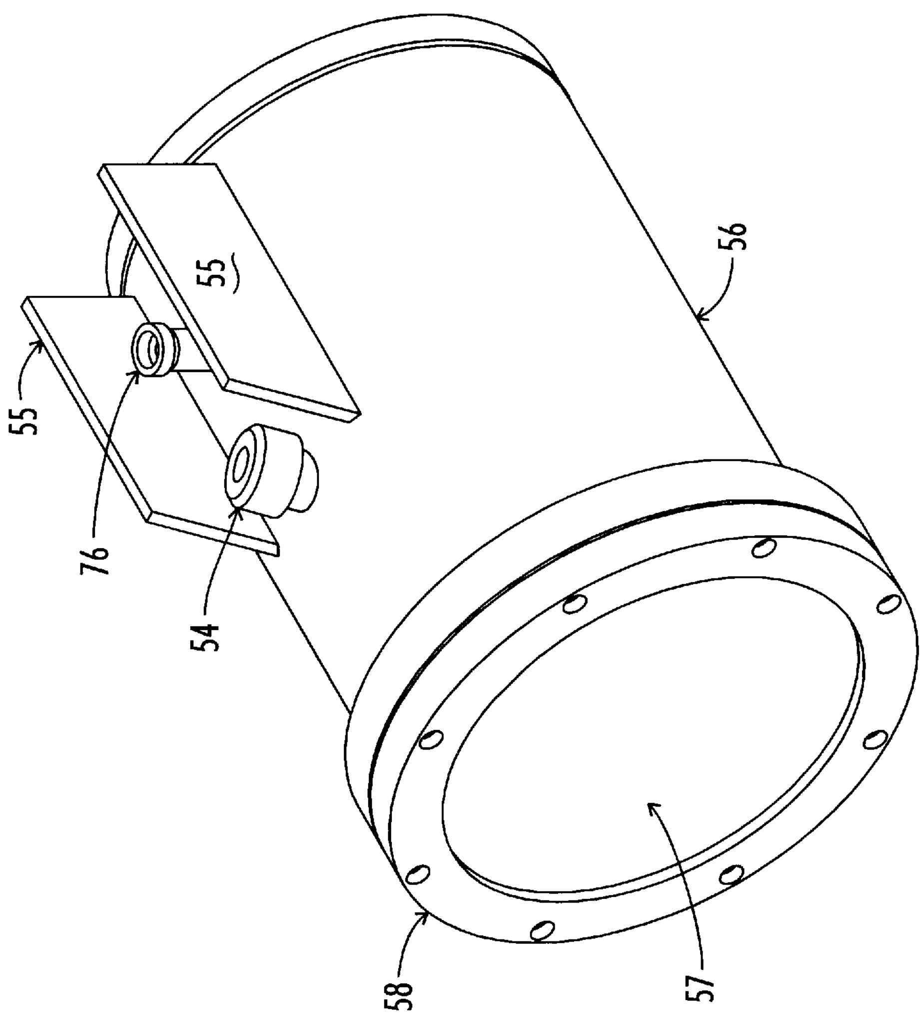


FIG. 3

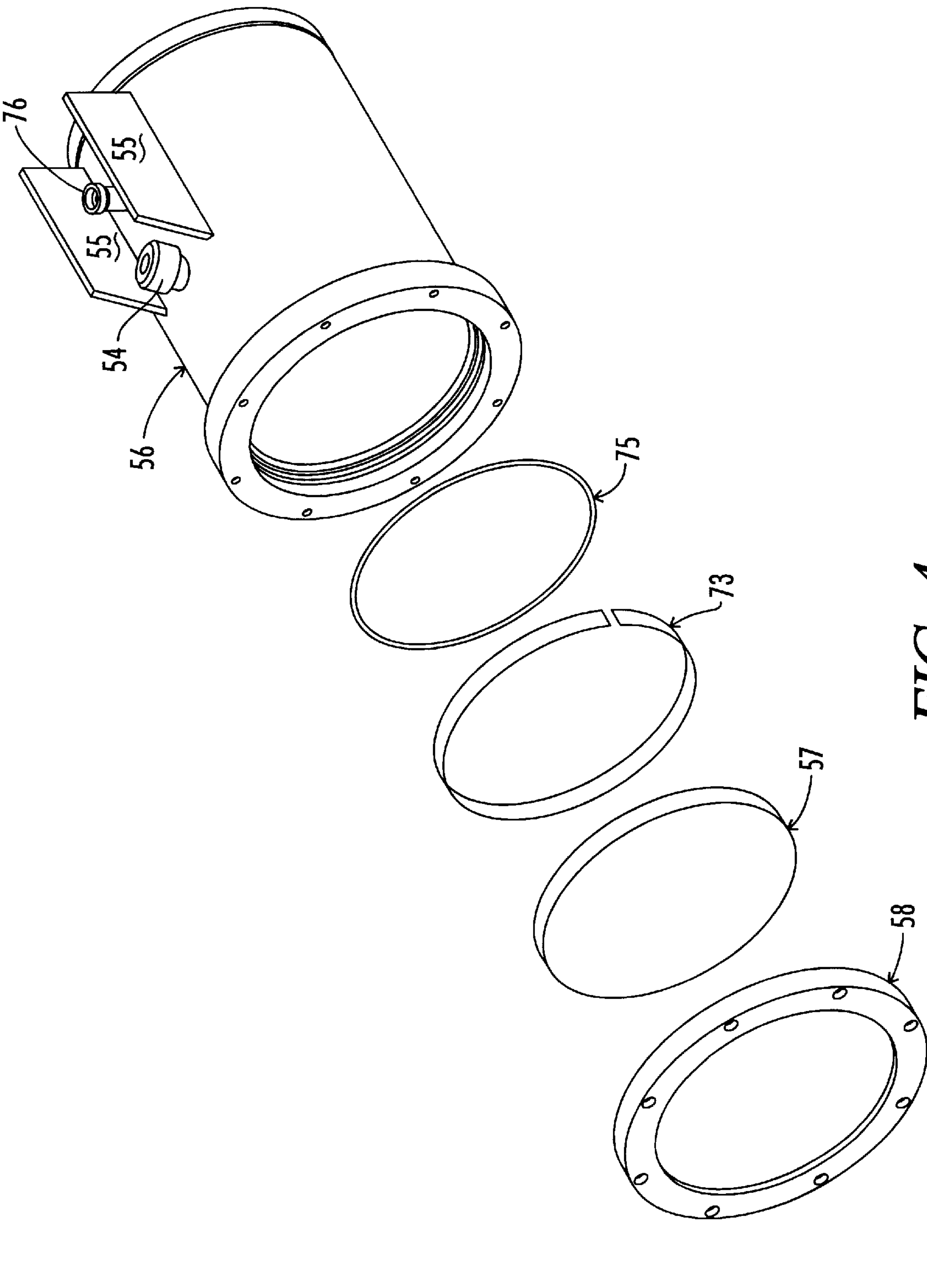


FIG. 4

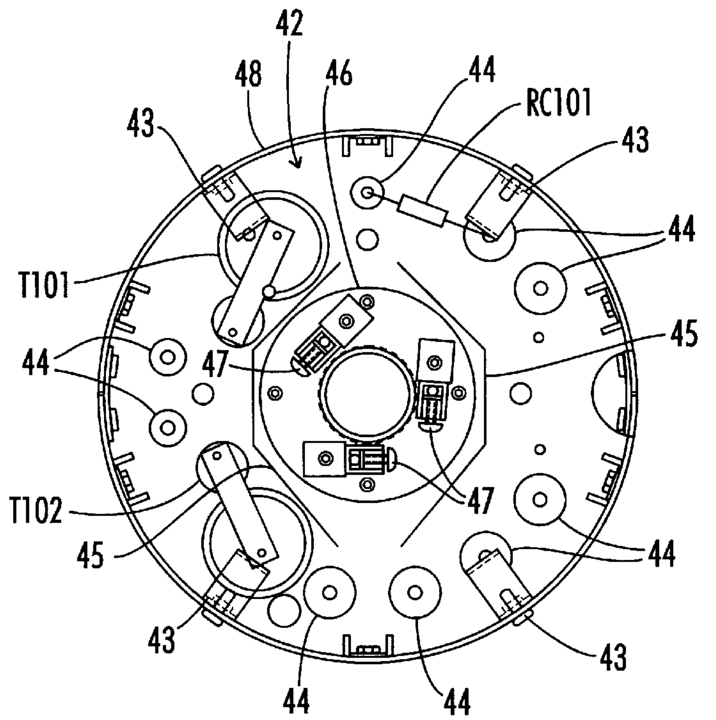

42
48
46
44
RC101
43
43
44
T101
45
44
47
47
T102
44
45
43
43
44
44

FIG. 6

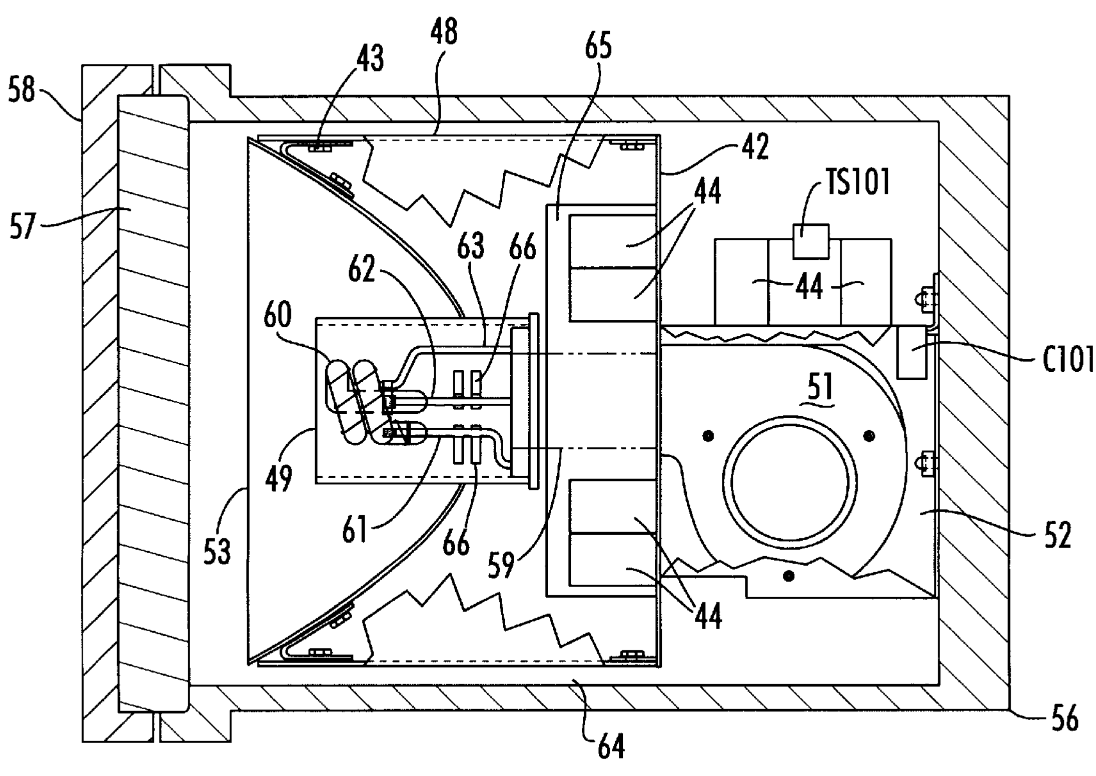
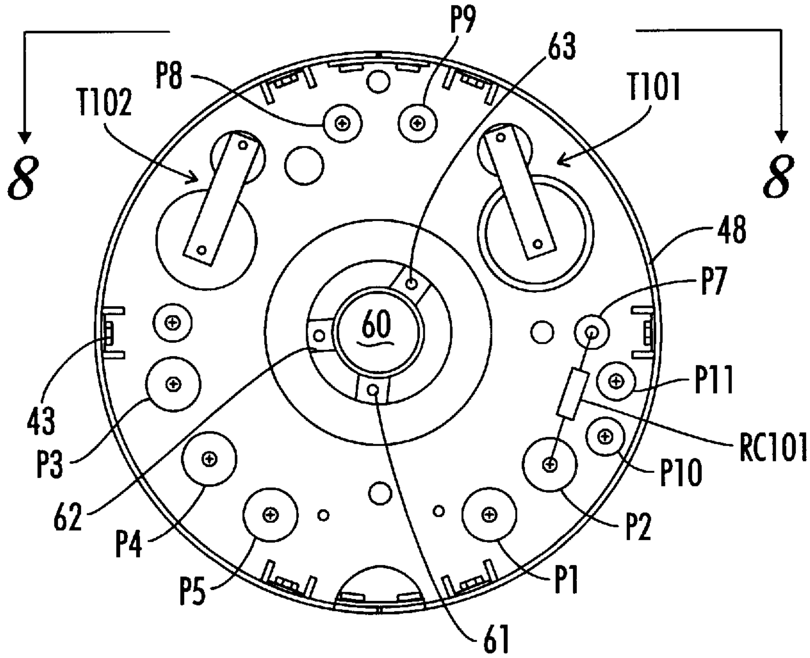
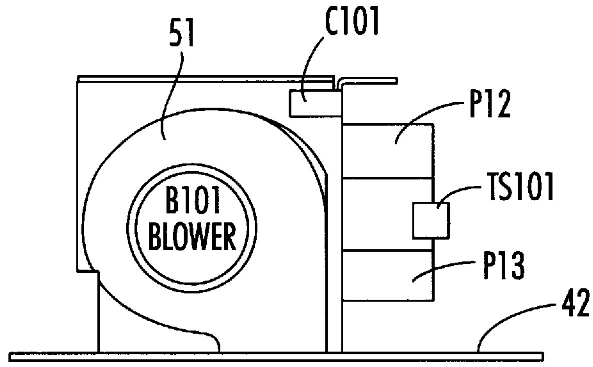

58
43
48
65
42
57
44
TS101
62
63
66
44
60
C101
51
49
52
53
61
66
59
44
56
64

FIG. 5



P9
63
P8
T102
T101
8
8
48
P7
60
P11
RC101
43
P3
P10
62
P2
P4
P5
P1
61

FIG. 7



51
C101
P12
B101
BLOWER
TS101
P13
42

FIG. 8

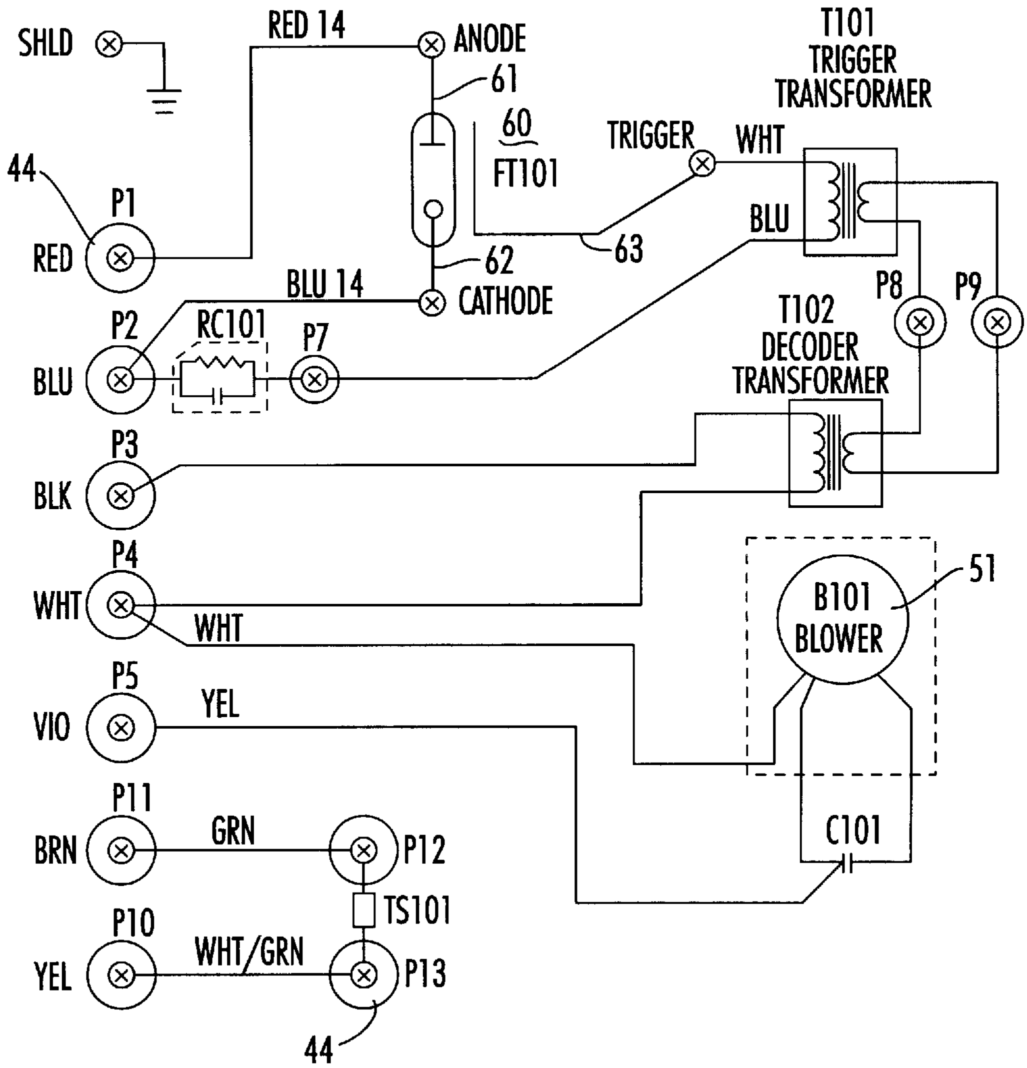

SHLD
RED 14
ANODE
61
60
FT101
T101
TRIGGER
TRANSFORMER
TRIGGER
WHT
BLU
63
44
P1
RED
62
BLU 14
CATHODE
P2
RC101
P7
BLU
P8
P9
T102
DECODER
TRANSFORMER
P3
BLK
P4
WHT
WHT
B101
BLOWER
51
P5
VIO
YEL
P11
BRN
GRN
P12
C101
TS101
P10
YEL
WHT/GRN
P13
44

FIG. 9

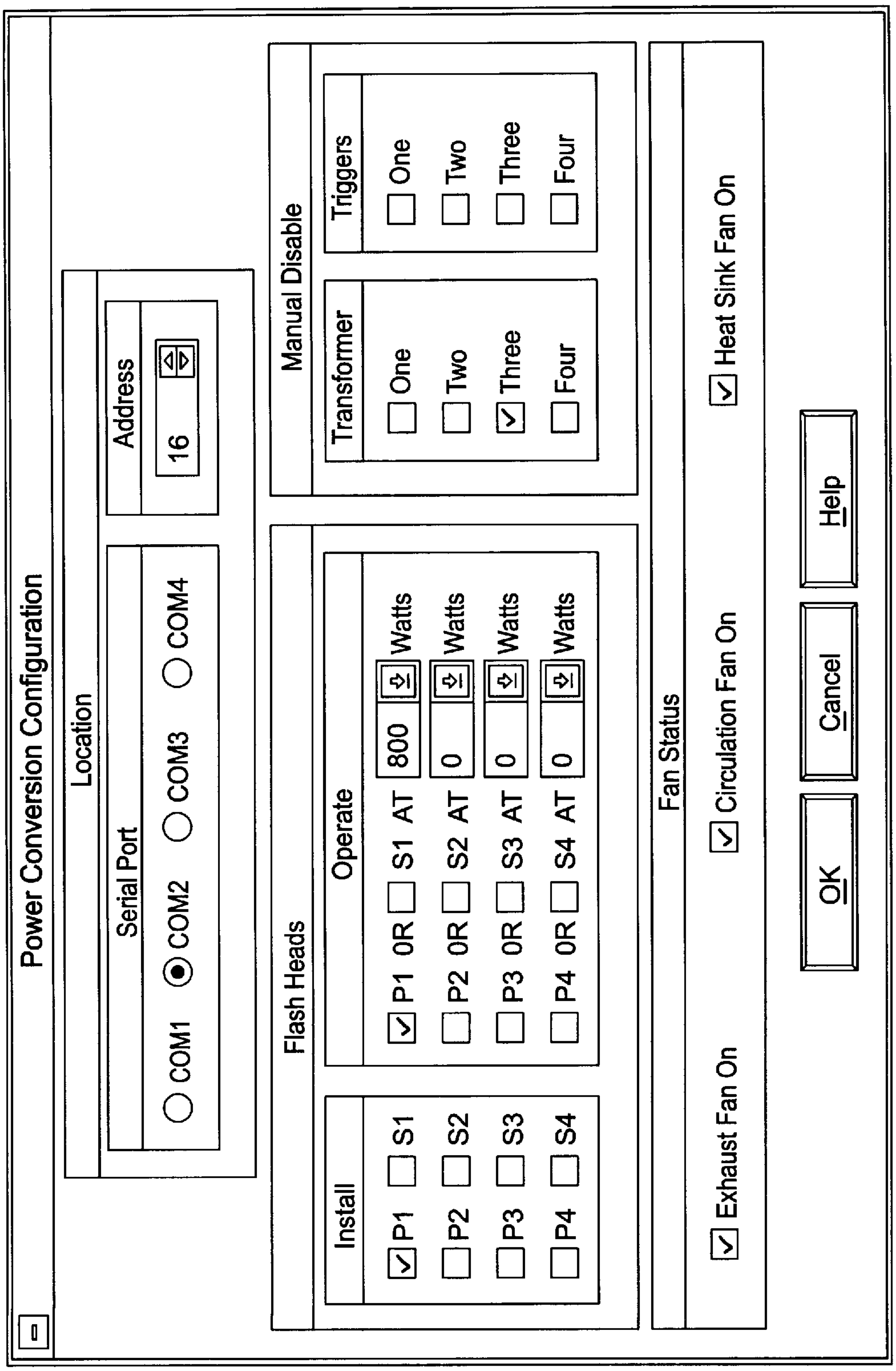

Power Conversion Configuration
Location
Serial Port
COM1
COM2
COM3
COM4
Address
16
Flash Heads
Install
P1
S1
P2
S2
P3
S3
P4
S4
Operate
P1 0R S1 AT 800 Watts
P2 0R S2 AT 0 Watts
P3 0R S3 AT 0 Watts
P4 0R S4 AT 0 Watts
Manual Disable
Transformer
One
Two
Three
Four
Triggers
One
Two
Three
Four
Fan Status
Exhaust Fan On
Circulation Fan On
Heat Sink Fan On
OK
Cancel
Help

FIG. 10

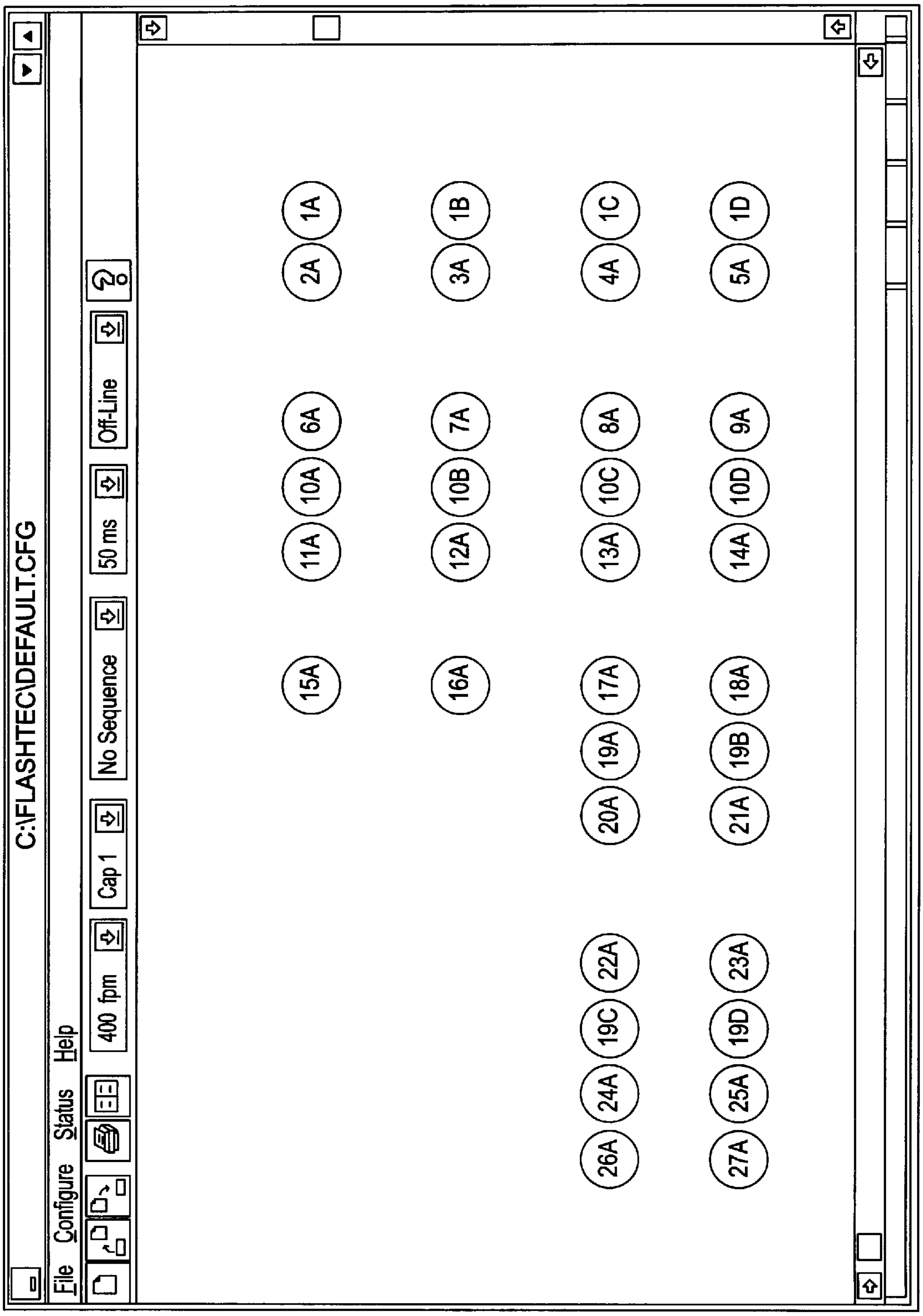

C:\FLASHTEC\DEFAULT.CFG
File Configure Status Help
400 fpm
Cap 1
No Sequence
50 ms
Off-Line
1A 2A 6A 10A 11A 15A
1B 3A 7A 10B 12A 16A
1C 4A 8A 10C 13A 17A 19A 20A 22A 19C 24A 26A
1D 5A 9A 10D 14A 18A 19B 21A 23A 19D 25A 27A

FIG. 11

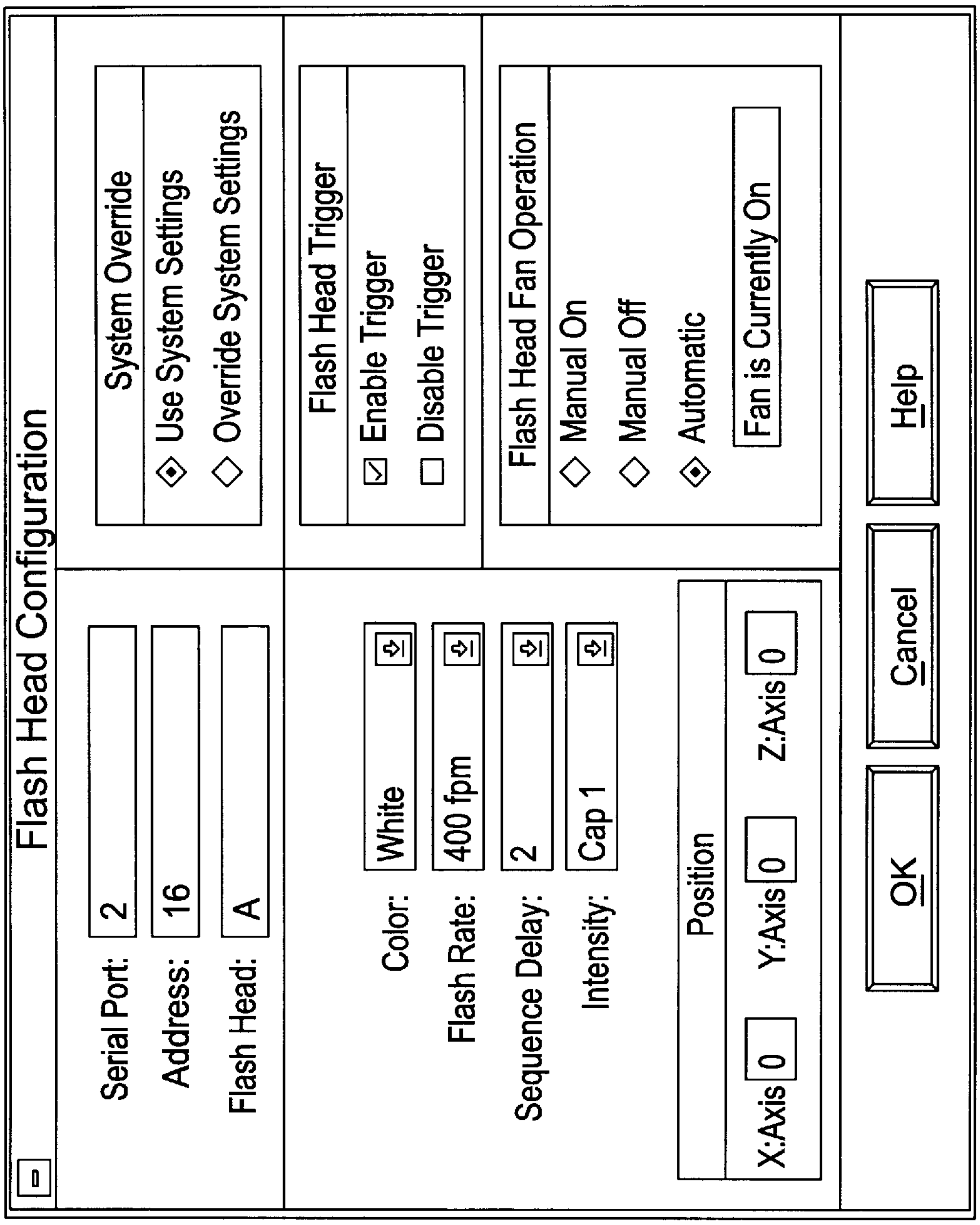

Flash Head Configuration
Serial Port: 2
Address: 16
Flash Head: A
Color: White
Flash Rate: 400 fpm
Sequence Delay: 2
Intensity: Cap 1
Position
X:Axis 0
Y:Axis 0
Z:Axis 0
System Override
Use System Settings
Override System Settings
Flash Head Trigger
Enable Trigger
Disable Trigger
Flash Head Fan Operation
Manual On
Manual Off
Automatic
Fan is Currently On
OK
Cancel
Help

FIG. 12

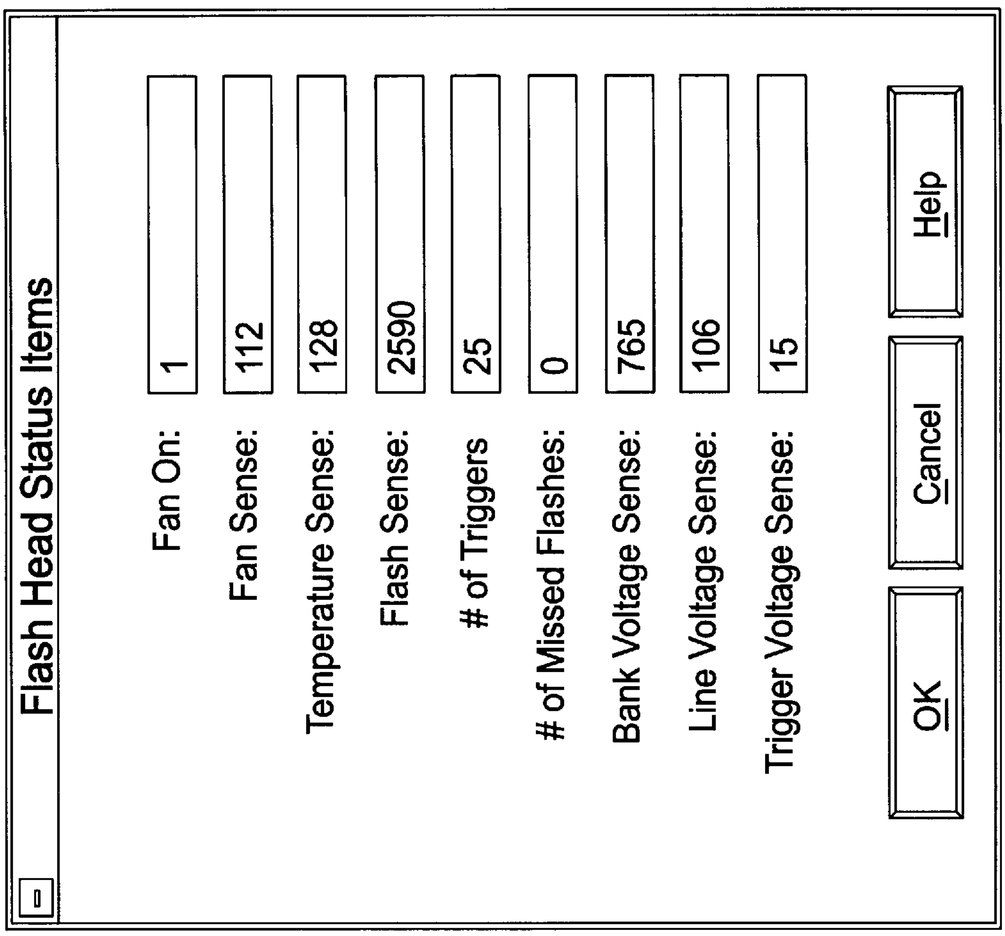

Flash Head Status Items
Fan On: 1
Fan Sense: 112
Temperature Sense: 128
Flash Sense: 2590
# of Triggers 25
# of Missed Flashes: 0
Bank Voltage Sense: 765
Line Voltage Sense: 106
Trigger Voltage Sense: 15
OK
Cancel
Help

FIG. 13

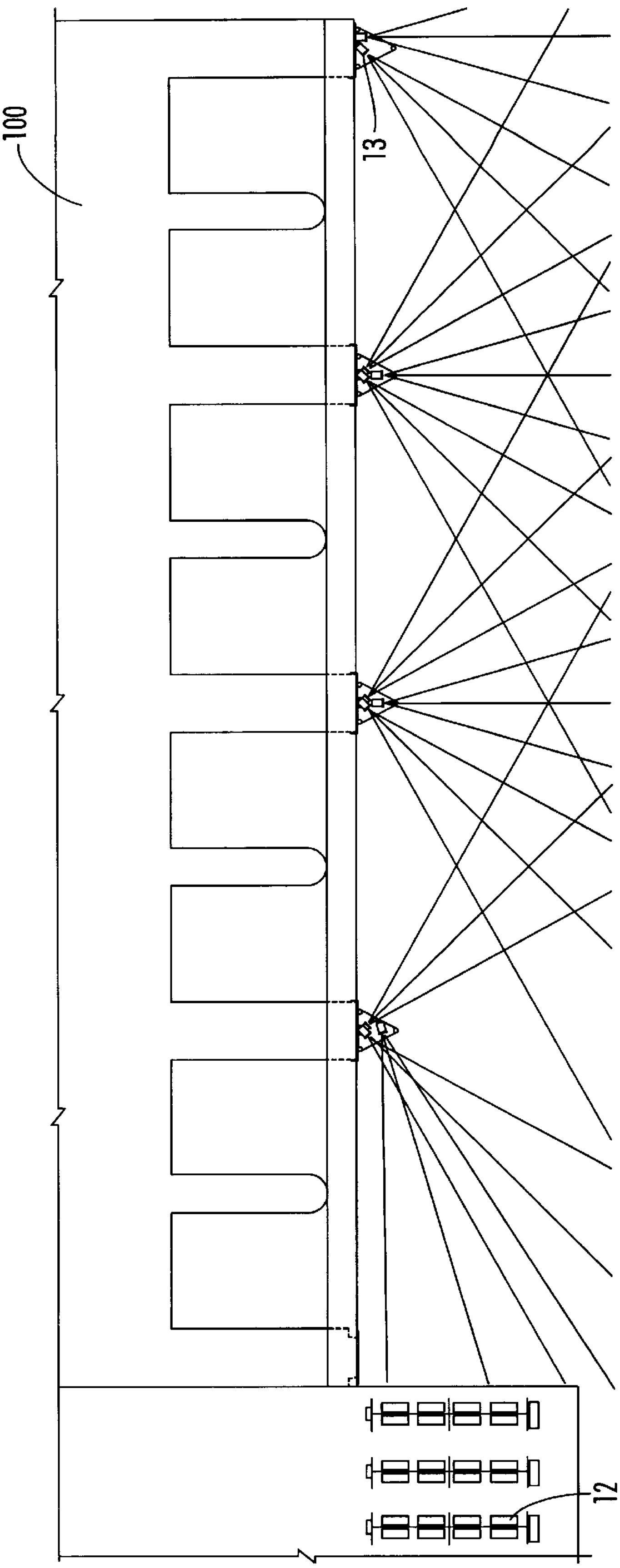


FIG. 14

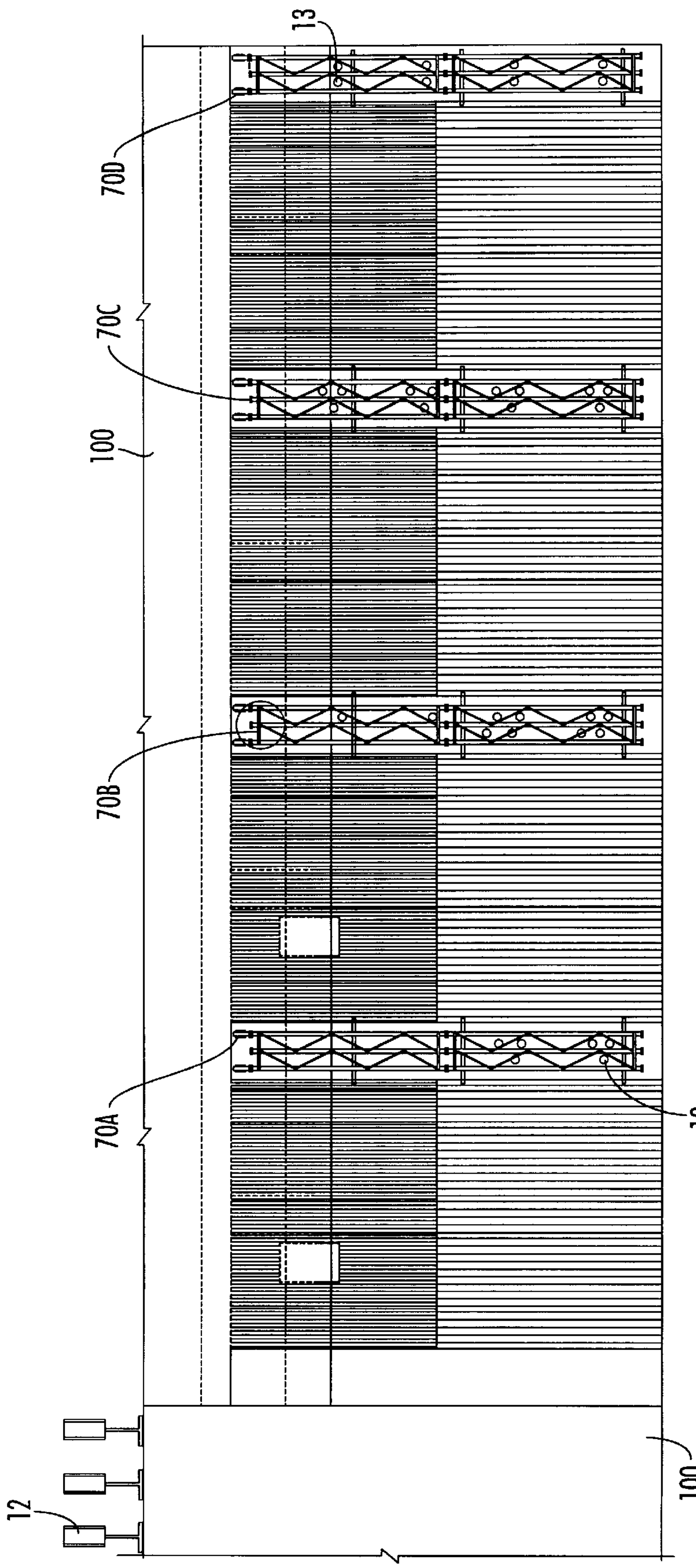


FIG. 15

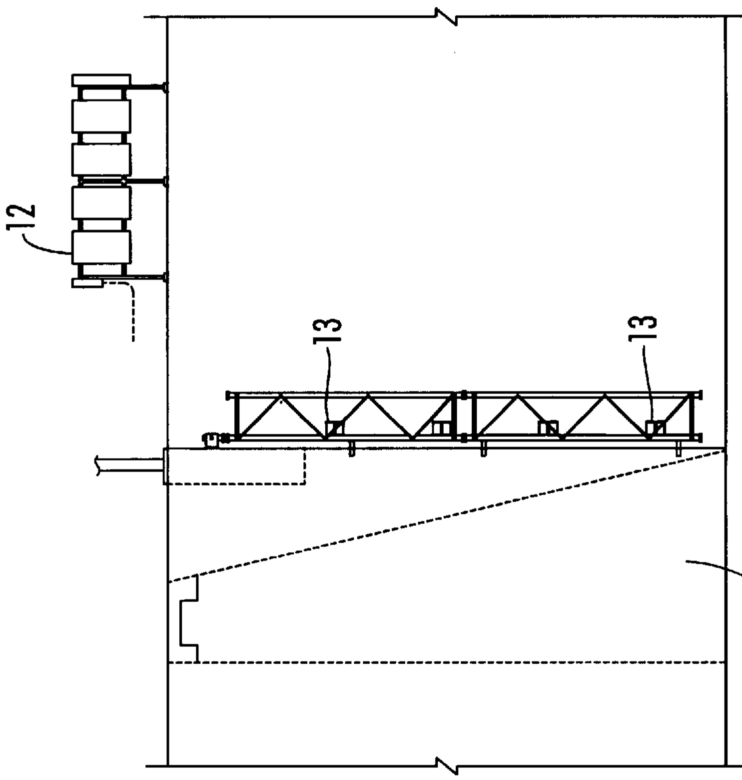


FIG. 16

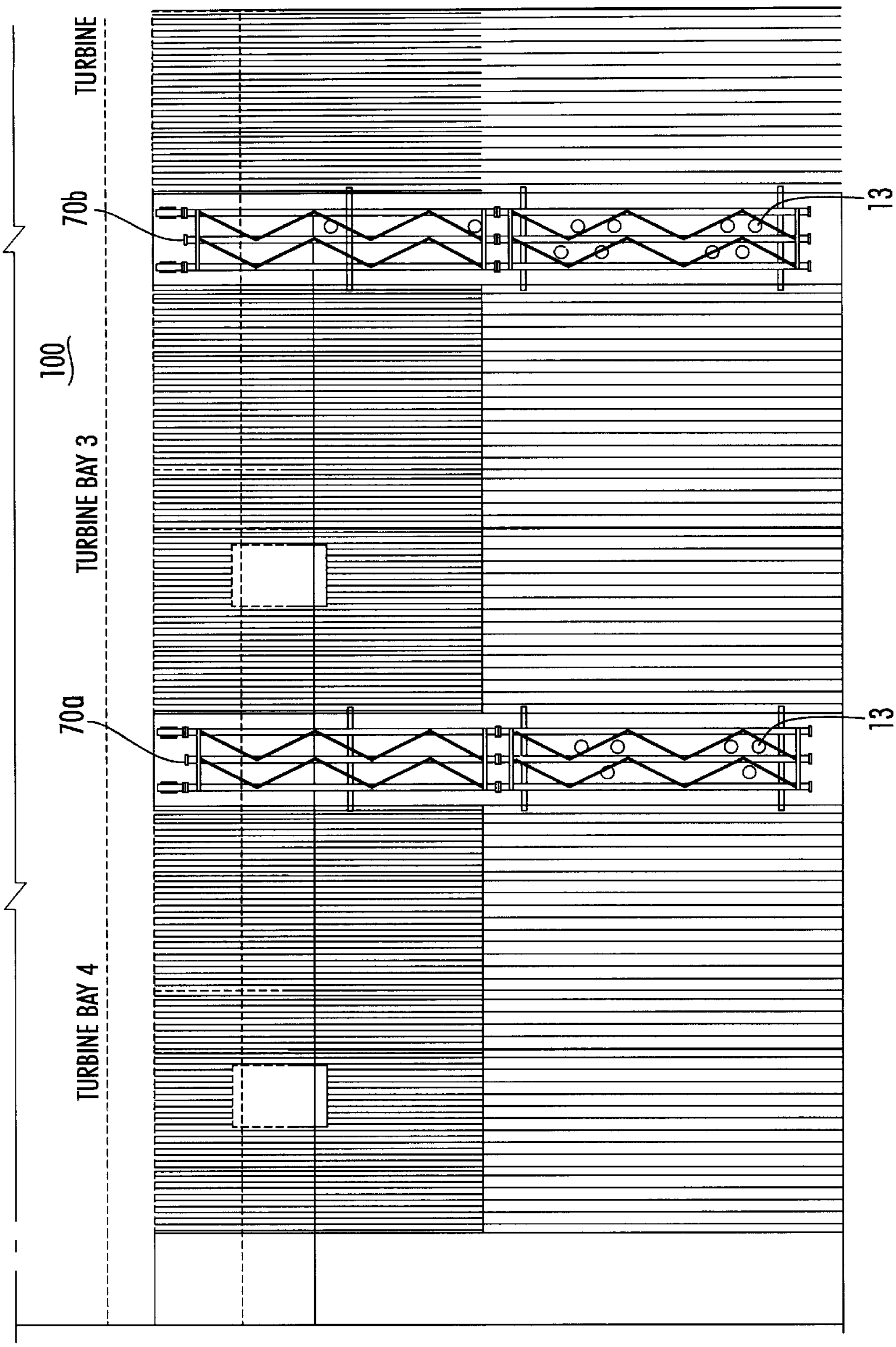


FIG. 17

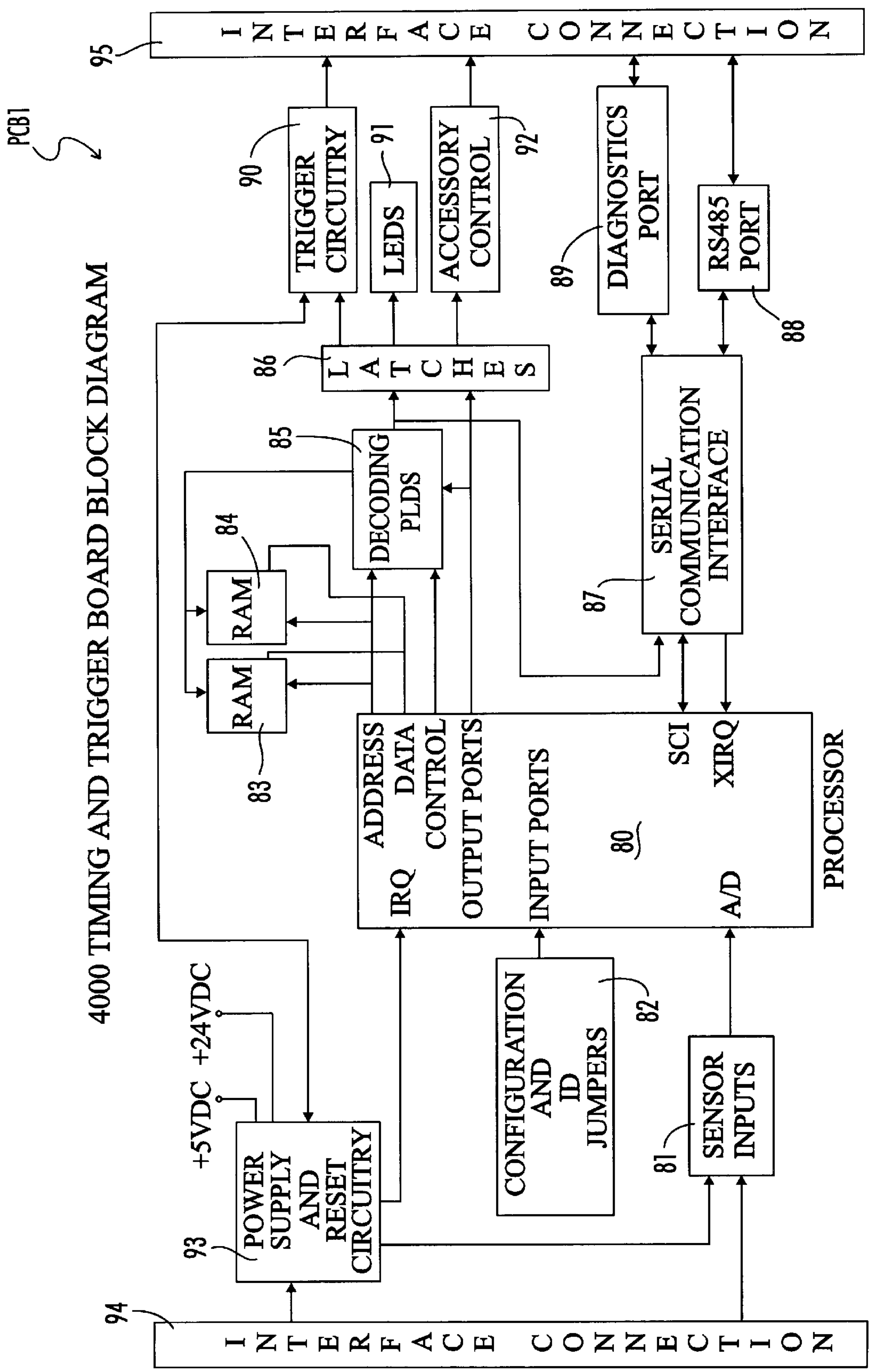

4000 TIMING AND TRIGGER BOARD BLOCK DIAGRAM
PCB1
95
INTERFACE CONNECTION
TRIGGER CIRCUITRY
90
LEDS
91
ACCESSORY CONTROL
92
DIAGNOSTICS PORT
89
RS485 PORT
88
LATCHES
86
DECODING PLDS
85
RAM
84
RAM
83
SERIAL COMMUNICATION INTERFACE
87
ADDRESS
DATA
CONTROL
OUTPUT PORTS
INPUT PORTS
IRQ
SCI
XIRQ
A/D
80
PROCESSOR
+5VDC
+24VDC
POWER SUPPLY AND RESET CIRCUITRY
93
CONFIGURATION AND ID JUMPERS
82
SENSOR INPUTS
81
94
INTERFACE CONNECTION

FIG. 18

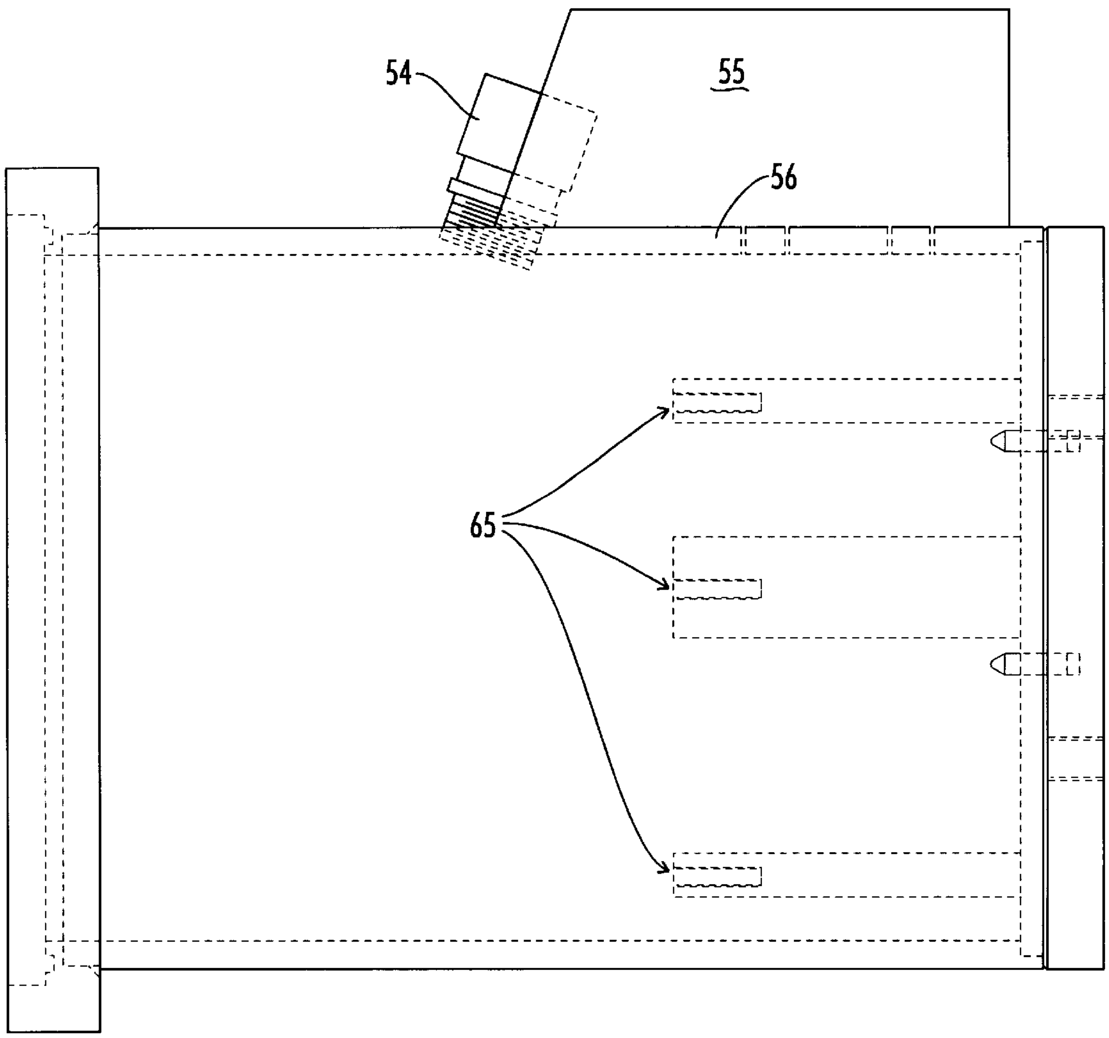


FIG. 19

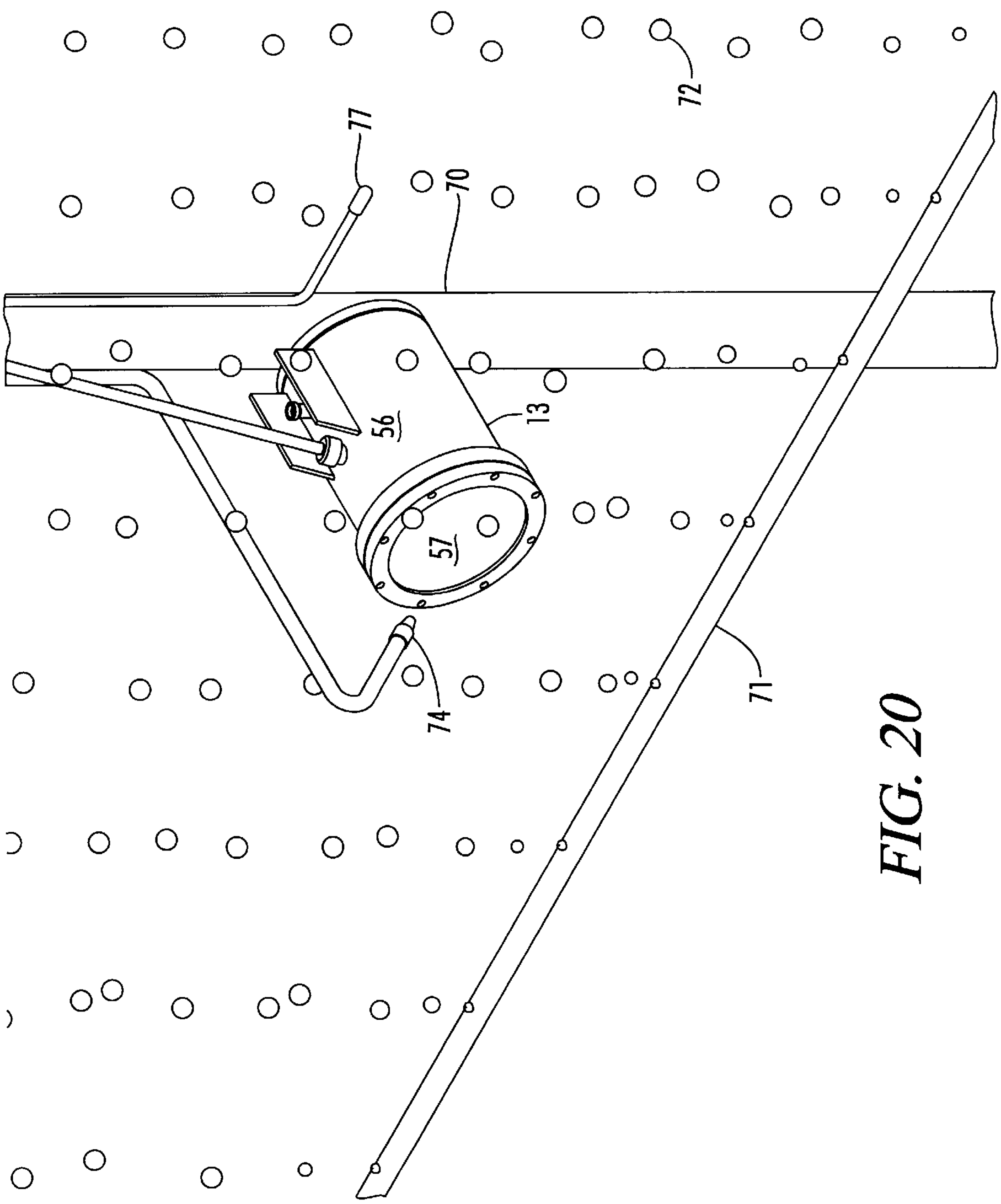


FIG. 20

CONTROLLABLE STROBE LIGHT SYSTEM AND METHOD FOR DIRECTING THE MOVEMENTS OF FISH

BACKGROUND OF THE INVENTION

The present invention relates generally to barriers and other devices used to repel or direct the movement of migrating fish away from turbine intakes and other danger points at dams, hydroelectric facilities, and water intakes in lakes and rivers. More particularly, the present invention describes a system for directing the movement of fish in which the system uses multiple underwater strobe lights strategically positioned and controlled to direct fish away from and towards desired locations.

Hydroelectric power plants and dams have been used throughout the United States and the world with great effectiveness in electric power generation, irrigation, and flood control schemes. However, the increasing use of obstructions across rivers and other navigable waterways has created problems of its own, including deleterious effects on fish populations. For example, hydroelectric dam turbine intakes are a natural attraction point for schooling and migrating fish. If fish are allowed to enter those intakes, large numbers of fish are killed in relative short periods of time. Such fish kills, in turn, can cause damage to the facilities themselves. Also, dams and other structures placed across rivers can interfere with the natural migratory patterns of fish that have been established over the years. If these fish are not allowed to pass the dam and are obstructed from following their natural migratory waterways, fish populations can be greatly impaired. Similar problems can occur at municipal and industrial water intake sites, where large numbers of fish can be drawn into the intake. Therefore, it is important that some means be provided to direct migrating fish around or through a dam, obstruction, or intake so that they can reach their natural spawning grounds.

In response to these issues, federal and state agencies have become increasingly active in establishing a regulatory scheme for the protection of fish in these environments. Accordingly, a variety of physical barrier technologies have been developed in the prior art. These prior art technologies include the use of barrier nets, fish lifts, racks, mesh screens, and louvered bypasses. Unfortunately, such physical barriers have not been optimally efficient in protecting or diverting fish. Moreover, the installation of physical barriers can be extremely expensive, in that custom barrier designs must be developed for each location. Ongoing maintenance costs are also a significant negative factor in the use of physical barriers to control fish.

As an alternative to the use of physical fish barriers, experiments have been conducted in the prior art in the use of strobe lighting as a means to repel fish or otherwise control or direct their movement as they confront or approach a dam or other water intake. These experimental studies have demonstrated that strobe lights produce strong avoidance behavior in a variety of fish species on a consistent basis. In addition, the fish who show this avoidance behavior do not show a tendency to become acclimated to strobe light stimuli, even after prolonged exposure.

The strobe light systems used in the prior art experiments for the control of fish behavior have been deficient in a number of respects, particularly in regards to the development of a commercially useful system which can be easily adapted, installed, and used in a wide variety of physical and aquatic environments and that can be used, without significant modification, to control the behavior of one or more of multiple fish varieties. Thus, for example, variations in ambient water turbidity, water flow rate, flow direction, and water temperature, can directly impact the efficiency of fish control using strobe light systems. In addition, experimentation relating to the development of the present invention has shown that adjustment of flash intensity, flash frequency, and flash sequence is necessary in order to optimally adapt a strobe light fish control system to a particular environment and to a particular species of fish. Prior art systems have not allowed this degree of flexibility and control leading, to the conclusion that such systems can only be considered to be experimental rather than commercially useful.

For behavioral control of fish during a short migration season, there is only a very narrow window of opportunity to adapt a strobe light control system to that species of fish and to the particular environmental conditions encountered. Therefore, real time reaction and control of the system to varying ambient conditions and fish behavior is an important factor. Such control is not found in any of the prior art experimental systems.

Another problem found with prior art strobe light fish control systems relate to the longevity of the crucial underwater portion of the system, that being the multiple strobe light flash heads. Much of the prior experimentation with such systems has been used in conjunction with flash heads mounted at or near the water surface, attached to floating structures. However, a universally adaptable, commercially useable fish control system using multiple strobe flash heads must be capable of installation at significant depths below the water line, up to perhaps one hundred-fifty feet. This produces a set of problems of its own, particularly in heat management. The preferred means of generating illumination from a strobe flash head is the xenon tube which is both durable and highly efficient. However, the heat generated by the xenon tube and related components must be carefully controlled, particularly in an underwater location, so that the flash head will not fail prematurely because of excessive heat buildup. Experimental prior art strobe light fish control systems have relied on relatively crude adaptations of strobe light devices which have not fully met the needs for deep water submersion, durability, and high flash intensity.

What is needed, then, is a system for the control of fish movement using strobe lights which can be easily installed and adapted to a wide variety of physical environments, can be controlled and adjusted to influence the behavior of a wide variety of fish species, and which carefully deals with flash head heat management in order to prolong the durability of the system.

SUMMARY OF THE INVENTION

One object of the present invention is to provide a system to direct the movement of fish near man-made structures that is reliable, efficient, flexible, easy to install, and easy to maintain.

Another object of the present invention is to provide a strobe light fish movement control system in which operational control and functioning of the system can be adjusted easily and in real time to adapt the system to changing water and other conditions near the structure.

Yet another object of the system of the present invention is to provide flash heads in a multiple flash head strobe light fish movement control system which can operate efficiently and continuously while submerged.

These and other objects of the invention which will be apparent to those skilled in the art are met by a strobe light fish movement control system in which multiple flash heads are linked through one or more flash head control units to a personal computer based system control unit. The system control unit and flash head control units include data communication services, status monitoring devices, and control links which allow an operator of the system to change and monitor the flash sequence, flash rate, and flash intensity. In addition, an air bubble curtain and water jets installed at or near the flash head allow the system to adapt to changing water conditions and fish varieties so that the system can be easily optimized for a particular environment.

The flash heads used in the system are configured for long life while submerged through the use of novel heat management features. An internal cooling fan and temperature sensor sends signals to the system so that appropriate heat control measures can be undertaken. An air plenum is formed around the flash tube inside the waterproof flash head housing so that air can be easily circulated, with an air passage way formed between the outside of the air plenum and the inner wall of the housing. A parabolic reflector enhances radiated light from the flash head and forms a top surface of the air plenum. Forced air is brought to the flash tube through an opening in the central portion of the parabolic reflector, thereby minimizing light loss.

Constant monitoring of flash rate, flash intensity, and flash head temperature prevents overheating of the flash tube in each flash head.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view showing the general arrangement of the system of the present invention, including the system control unit, multiple flash head control units, and multiple flash heads.

FIGS. **2***a*, **2***b*, **2***c*, and **2***d* collectively are a schematic diagram of a flash head control unit as used in the present invention, with each flash head control unit including four flash head control circuits which are separately illustrated on each drawing page.

FIG. **3** is a perspective view of a single flash head as used in the system of the present invention.

FIG. **4** is a perspective view of a single flash head, partially exploded to show the lens and lens clamping ring.

FIG. **5** is a cut-away side view of a single flash head.

FIG. **6** is a plan view of the flash head showing the plenum shroud and components internal thereto.

FIG. **7** is a plan view of the flash head interior to the plenum shroud, with the parabolic reflector removed, showing the location of electrical components and connection terminals.

FIG. **8** is a view taken along lines A-A of FIG. **7**, showing the blower portion of the flash head.

FIG. **9** is a schematic diagram of the flash head electrical system.

FIG. **10** is a drawing of a typical video display screen generated by the software used in the system control unit, allowing the user to configure operation of a flash head control unit.

FIG. **11** is a typical video display screen generated by the software of the system control unit, illustrating a configuration of the system for all flash heads.

FIG. **12** is an illustration of a typical video display screen presented to an operator of the system at the system control unit when configuring an individual flash head.

FIG. **13** is an illustration of a typical video display screen generated by the software of the system control unit when monitoring the operational status of a specific flash head.

FIG. **14** is a plan view of the system of the present invention showing a typical installation adjacent to an hydroelectric facility having multiple turbine intakes.

FIG. **15** is a front or side view of the system installation of FIG. **14**, showing placement of the flash heads below the water line.

FIG. **16** is an end view of the installed system of FIGS. **14** and **15**.

FIG. **17** is an enlarged side view of the installed system of FIGS. **14**, **15**, and **16**.

FIG. **18** is a block diagram of the electrical subsystems associated with the flash head control unit of the system, including the timing and trigger board.

FIG. **19** is a cutaway side view of the flash head housing also showing the interior mounting posts.

FIG. **20** is a perspective view of a single flash head as installed in the system underwater, showing a preferred arrangement of the air bubble curtain and a corresponding water jet.

DESCRIPTION OF THE PREFERRED EMBODIMENT

System Overview

The fish movement control system is designed to provide an improved solution to the problem of entrainment of aquatic life in hydroelectric power plant intakes, pump-back station intakes, spillway intakes, and the like. FIG. **1** shows a general arrangement of the system **10** prior to installation near the structure where fish control is desired. A set of multiple flash heads **13** operated in a pre-determined sequence provide the strobed illumination used to direct movements of fish when the flash heads **13** are installed underwater near a structure. Each flash head **13** is connected by a power and control cable **17** to a flash head control unit **12**. Preferably, to minimize component redundancy and increase the efficiency of installation, multiple flash heads **13** are controlled by a single flash head control unit **12**. Thus, in FIG. **1**, a total of twenty flash heads **13** are controlled by five flash head control units **12***a*, **12***b*, **12***c*, **12***d*, and **12***e*, with four flash heads **13** controlled by a single flash head control unit **12**. Accordingly, each flash head control unit **12** will have multiple flash head control circuits. Signal processing, timing, and trigger control functions are provided by a timing and trigger board associated with each flash head control unit **12**, as shown on FIG. **18**.

In some aquatic environments, it may be desired to provide illumination wavelengths at each flash head **13** which are selectable by the system operator, after the flash heads are installed. In those situations, a flash head **13** may have two or more illumination devices and associated trigger circuits, with the flash head control unit allowing the system operator to switch between illumination devices and circuits to vary the flash wavelength. The respective illumination devices (xenon tubes **60** on FIG. **5**) will have different color filters associated with them so that flash wavelength is selectable.

Overall control functions for system **10** are performed by system control unit **11**, which preferably includes a personal computer **30** operatively combined with keyboard **31** and a mouse **33** to allow the operator of system **10** to enter system commands. The operator can monitor the operation of system **10** by viewing at video display **32** information that is displayed by the software being executed by personal computer **30**. Data communications to and from system control unit **11** and each flash head control unit **12** are implemented by a serial data communications interface, including communications I/O cable **15**.

Electrical power is provided to each flash head control unit **12***a*, **12***b*, **12***c*, **12***d*, and **12***e* from a power interface panel **14** having a power input cable **19** connected to a conventional A/C power supply at the location of the structure, with operational power then being delivered to each flash head control unit **12** by power output cables **18**.

System **10** also includes, in a preferred embodiment, a conventional air compressor (not shown) which has an "on/off" control input, connected to an output relay in a flash head control unit **12** with an air line **71** (FIG. **20**) extending into the water around the system **10**. This gives system **10** the capability of generating an underwater air bubble curtain near one or more flash heads **13** as installed. The air bubbles **72** enhance light dispersion and reflection, making the strobed lights more visible to the fish.

A conventional water pump (not shown) can also be used in conjunction with system **10**, the purpose of which is to supply high pressure water to a water jet **74** (FIG. **20**) directed at the lens area of each flash head **13**. The water jets can be used to remove scum that may build up on the surface of lens **57**.

Also looking at FIG. **20**, a temperature probe **77** is shown positioned in the water near mounting rack **70** and a flash head **13**. Probe **77** provides ambient water temperature data to system control unit **11** for use as described below.

System Control Unit

An important aspect of the system **10** is the high level of control and monitoring provided by system control unit **11**. Coordinating and controlling communications to and from all subsystems, the system control unit **10** provides both overall control and complete monitoring of all aspects of system operation. At least one system control unit is required per system **10**. The system control unit **10** performs the following functions:

a. monitor and control serial data communication to and from each flash head control unit;

b. monitor and control communications from a remote control station using the remote control and monitoring software, via a data modem and conventional phone line;

c. generate and implement a user interface via the video display **32** to enable the entry of system commands and to report system status;

d. provide on/off control signals to an air compressor for generation of a bubble curtain at each flash head **13**;

e. generate on/off control signals to a water pump to provide for water jet output at each flash head **13**;

f. generate control signals for flash head cooling devices;

g. provide control signals to enable/disable flashing of each flash head **13**;

h. configure and control flash head strobe sequence, including sequential ordering, flash spacing, and flash timing;

i. provide control signals to vary the flash intensity of one or more flash heads **13**;

j. monitor and report water temperature proximate to each flash head;

k. monitor and report flash intensity at each flash head;

Each system control unit **11** includes the following external inputs: communications with up to **128** flash heads **13**; communications with remote control/monitoring software via modem and analog phone line; input from one or more temperature probes **77**; computer keyboard **31** and mouse **33**.

In addition, each system control unit **11** has provisions for the following external outputs: communications with up to **128** flash heads **13**; communications with remote control/monitoring software; a video display **32**; a printer (not shown); and relays (or similar device) to turn on/off an air compressor and water pump.

The system control unit **11** is under the control of software designed for system **10** that, subject to system commands entered by the operator, includes routines to provide the following control services: print/display status report; log system activity to a printer; and enable/disable flashing on one, multiple or all flash heads **13**; allow the configuration and initiation of flashing lights on separate flash heads **13** in a operator selected sequence; change flash intensity on one, multiple or all flash heads **13**; turn air compressor on/off for bubble curtain output at flash heads **13**; turn water pump on/off for water jet output at flash heads; turn flash head cooling fan on/off on one, multiple or all flash heads **13**; and generate alarms/warnings (including communications errors) for all parts of the system **10**.

The system control unit software also preferably includes monitoring routines to provide the following monitoring and reporting services: water temperature at each flash head; flash intensity at each flash head **13**; and internal flash head **13** temperature.

Flash Head Control Units

Each flash head **13**, in conjunction with its corresponding flash head control circuit in a flash head control unit **12**, contains an illumination device and related hardware used to attract and deter fish. In most cases, an installed system **10** will contain multiple flash heads **13** to adequately cover the area being serviced. The exact number of flash heads **13** used is dependent on many system parameters including the width and depth of the body of water, the system orientation to the body of water, and the relative locations of the areas where fish are to be directed away from and towards.

A flash head **13** is electrically connected via power and control cable **17** to its respective control circuit in a flash head control unit **12**, and operatively connected to system control unit **11**, to coordinate its activities with other flash heads and to provide operational monitoring feedback.

Each flash head **13** will preferably include the following external inputs: communications with its flash head control unit **12** (via cable **17**, and including cooling fan control signals, and flash tube A and B trigger signals); water temperature; and internal flash head temperature. Each flash head **13** has provisions for the following external outputs: communications with a flash head control unit **12** (cable **17**, including flash head temperature and water temperature).

FIGS. **2***a*, **2***b*, **2***c*, and **2***d* collectively are an electrical schematic of the analog circuitry in single flash head control unit **12**. FIG. **18** is a block diagram of the digital section of the flash head control unit, also referred to as the timing and trigger board **PCB1**. The connections to the timing ands trigger board **PCB1** are labeled on FIGS. **2***a*, **2***b*, **2***c*, **2***d* as "**PCB1**, Jx", where x corresponds to a connector pin. In the preferred embodiment of system **10** shown in FIG. **1** and FIGS. **2***a*–**2***d* , a single flash head control unit **12** is configured to provide power to and communications with up to eight attached flash heads **13**, represented in FIGS. **2***a*–**2***d* as flash heads **A1**, **B1**, **A2**, **B2**, **A3**, **B3**, **A4**, and **B4**. In this embodiment, a single flash head housing **56** will enclose one flash tube **60** with related triggering circuitry. Thus, looking at FIG. **2***a*, a flash head **13** will include one flash tube **60** having its own flash head control circuit within flash head control unit **12**. Therefore, there will be a total of eight flash head control circuits, selectable between four flash heads A or four flash heads B, in a single flash head control unit **12** of FIGS. **2***a*, **2***b*, **2***c*, and **2***d*. Applicant herein will describe the interconnection and functioning of a single flash head control circuit, as illustrated on FIG. **2***a*, with the understanding that the same description will apply as well to the flash head control circuits illustrated also on FIGS. **2***b*, **2***c*, and **2***d*. Optionally, multiple flash tubes **60** with associated trigger circuitry can be installed in a single housing **56** and controlled in a similar manner.

Looking now at FIG. **2***a*, conventional 120 VAC electrical power is supplied to each flash head control unit **12**, from power interface panel **14**, through a power cable **18**, connected at terminal block TB**201**. Input power sense board PCB**6** (FIG. **18**) senses the presence of input power being supplied to flash head control unit **12** and sends a signal accordingly to system control unit **11**. Input power is then distributed to various points as shown throughout flash head control unit **12**, beginning with interconnections at terminal block TB**8**. Thus, for those circuits and components requiring a DC supply voltage, AC power is sent to first high voltage rectifier board PCB**12** which is connected at terminal block TB**13**. Lamp **1201** provides visual indication of power being energized. For devices and components needing AC supply voltage, timing board PCB**1** and temperature sense board PCB**4**, for example, the 120 VAC supply is stepped down as needed at power transformer T**11**. Fuse F**201** provides current overload protection and switch S**11** is a safety interlock device that removes power when the front panel of the flash head control unit **12** is opened.

A bank of capacitors C**11**A, C**11**B, C**11**C, C**12**, and C**13** are provided, in conjunction with capacitor select relays K**11** and K**12**, as a means for selectably adjusting the flash intensity of the corresponding flash head **13**. Table I shows the range of selectable flash rates, corresponding to different capacitor selections and power settings.

TABLE I

SELECTABLE FLASH RATES, CAPACITOR SETTINGS AND POWER SETTINGS SHOWING POWER OPERATING RANGES

Flashes per Minute	Max Number of Capacitors Selectable	Range of Operational Power (Watts)
60	4, 3, 2, or 1	640 to 20
72	3, 2, or 1	
75		
80		833 to 24
90		
100		
120	2 or 1	733 to 40
144		
150		
180		
200		
225	1 only	300 to 800
240		
300		
360		
400		
450		
600		

CAP4 AT 800 W=1280 mF

CAP4 AT 200 W=320 mF

CAP3 AT 800 W=1000 mF

CAP3 AT 200 W=250 mF

CAP2 AT 800 W=440 mF

CAP2 AT 200 W=110 mF

CAP1 AT 800 W=160 mF

CAP1 AT 200 W=40 mF

Thus, the system operator can enter a system command at system control unit **11** a particular flash intensity as part of the flash head configuration routine. The flash intensity selection is implemented by a corresponding flash intensity select signal being sent to relays K**11** and/or K**12**.

The software in system control unit **11** is pre-programmed with the parameters set forth in Table I which determine the safe operational limits of the particular flash head **13**, to avoid overheating of the flash tube. Accordingly, system control unit internally monitors the configuration of each flash head **13**, to prevent selection of flash head operational parameters which would expose the flash tube to an overheating condition. Subject to these limits, in a preferred embodiment of system **10**, each flash head can be operated from between 20 to 800 watts with the flash rate adjusted on real time basis from between 60 to 600 flashes per minute. Depending on local ambient and operating conditions, on-site adjustment of the system may be needed to deal with heat management issues. If overheating of the flash heads becomes a problem, a preferred method of solving the problem is to reduce flash head duty cycle by increasing the number of flash heads.

A trigger coupling transformer T**13** receives flash trigger signals from timing and trigger board PCB**1** (FIG. **18**). The flash trigger signals are transmitted to either flash head A**1** (flash head **13**A) connected at terminal block TB**203** or to flash head B**1** (flash head **13**B) connected to terminal block TB**207**. Selection of either flash head A**1** or flash head B**1** on FIG. **2***a* is made by trigger and fan steering relays K**15** and K**16** which are responsive to flash head select signals received from timing and trigger board PCB**1**.

A flash tube current sense transformer PCB**14** has its primary winding connected to the anode of each flash tube within flash head A**1** and flash head B**1**. The secondary winding of flash tube current sense transformer PCB**14** is connected to timing and trigger board PCB**1** so that an appropriate signal can be sent to system control unit **11**, verifying functioning of the flash tube.

Steering relays K**15**/K**16** also control the switching of data from corresponding temperature sensors TS**101** associated with flash head A**1** or B**1**, which is electrically connected at terminal block TB**211**. This data, preferably generated from a conventional thermistor type sensor, is then sent to temperature sensing board PCB**4**. Also, flash head fan sense module PCB**15** confirms operation of a corresponding flash head fan (blower **51** on FIG. **5**), sending a confirming signal to timing and trigger board PCB**1**.

Power selection relay K**1**, in response to a signal from timing and trigger board PCB**1**, varies the operating power in response to flash rate and intensity selections.

A tuning capacitor C**14** is connected across a primary winding of power transformer T**11** to assist in regulation of the secondary output voltage.

Discharge relay K**4**, unless closed by a signal from timing and trigger board PCB**1**, enables flashing of each flash head **13** connected to flash head control unit **12**, by allowing discharge of current from a corresponding flash tube **60** through discharge resistor R**1**.

FIG. **2***c* also schematically illustrates the serial data communications connections to the flash head control unit

12. In this embodiment, the data is transmitted and received using an industry standard RS485 serial communications link and protocol, connected at terminal blocks TB**213** and TB**214**, with the data being sent to and received from timing and trigger board PCB**1**.

FIG. **2***d* schematically shows a series of six blowers B**1**, B**2**, B**3**, B**4**, B**5**, and B**6** which work together to internally circulate and exhaust air from flash head control unit **12**. Operation of blowers B**1**–B**6** is controlled by blower control relays K**8** and K**9** in response to signals received from timing and trigger board PCB**1**. Blower sense modules PCB**7**, PCB**8**, PCB**9**, sense operation of blowers B**1**, blowers B**2**, B**3**, B**4**, and blowers B**5** and B**6**, respectively, and send corresponding signals indicating proper operation of the blowers to timing and trigger board PCB**1**.

FIG. **18** illustrates the various functional blocks of timing and trigger board PCB**1** and their interconnection. Basic flash head control is provided by a conventional microprocessor **80** which receives analog data input from the system **10**, shown as block **81**, and performs a multiplexed analog-to-digital conversion of that data (flash head temperature, capacitor bank voltage, line voltage, trigger voltage, and flash sensing) of the system **10** to configure and adapt processor **80** to perform the functions required by the system. A random access memory chip **83** provides static memory for use of processor **80** while a read only memory chip **84** (EPROM) contains the software which provides the basic operating system functions for the processor **80**.

The outputs from processor **80** to system **10** are provided through decoder block **85** and latch block **86**. These in turn provided trigger signals through trigger circuit **90** to trigger operation of flash tubes **60** in the various flash heads **13**, through the circuitry shown on FIGS. **2***a*–**2***d*. Visual indication of operation of the system is also provided through a light emitting diode block **91**. Finally, control of the various system signals for operation of system accessory devices, specifically the air compressor and water pump, are provided through accessory control block **92**. Serial communications between the timing and trigger board PCB**1** and the system control unit **11** are provided through a serial communications interface **87**, which includes both a system diagnostics port **89** and a conventional RS45 serial port **88**. Interface output connector **95** mechanically and electrically connects the outputs from timing and trigger board PCB**1** to the other corresponding sections of system **10**. Power for timing and trigger board PCB**1** is provided through a power supply and reset circuit **93** which sends power reset and interrupt signals to the processor **80** at start up and reset of system **10**. Analog input signals are provided to timing and trigger board PCB**1** through input interface connector **94**.

Flashheads

FIGS. **3**, **4**, **5**, and **6** illustrate the structure and internal arrangement of components used in flash head **13**. Because in a typical installation of system **10**, each flash head **13** will be submerged in a body of water associated with a fixed structure to be protected by the system **10**, each flash head **13** includes a water proof protective outer housing **56** having an opening at one end covered by a light transmissive lens **57** sealed with a circumferential retaining ring **58**, a lens shim **73**, and o-ring seal **75**. In a preferred embodiment of the flash head **13**, the housing **56** will be fabricated from type 6061 Aluminum. The lens **57** is made of tempered borosilicate glass. A water tight cable fitting **54** (FIGS. **3** and **4**) extends from and through housing **56** to allow for entry of the power and control cable **17**. Two parallel plates **55** are welded to housing **56** as trash shields and to protect cable fitting **54**. A gas fitting **76** is also provided to allow for air/gas injection and evacuation if desired.

The selection and arrangement of components internal to flash head **13** illustrates some of the novel features of system **10**, as implemented in flash head **13**, which optimally adapts the flash heads **13** for extended use in a submerged environment. The flashed illumination from flash head **13** is provided by a flash tube **60**, preferably a xenon flash tube, supported by a flash tube mount **46** (FIG. **6**.) and enclosed within a protective Pyrex glass cylinder **49**. Each flash tube **60** will include three rigid electrical connections attached to flash tube mounting lugs **7** supported by flash tube mount **6** (FIG. **6**). The electrical connections are anode **61**, cathode **62**, and trigger input **63**.

Because of the tremendous energy and heat generated by flash tube **60** when triggered, special novel heat management precautions have been taken in the design of flash tube **13**. First, an electrically powered blower **51** is mounted below flash tube **60** to force air around flash tube **60** through a Pyrex glass air duct **59**. Blower **51** is mounted to the inner portion of the bottom wall of enclosure **56** by blower base plate **52**. An annular parabolic reflector **13** circumferentially surrounds flash tube cylinder **49** to maximize the amount of light directed outward of flash head **13** through lens **57**. Because of the desire to maximize flash intensity in a submerged location, parabolic reflector **53** includes a centrally disposed annular opening to allow passage of air duct **59**, thus minimizing the loss of light due to impairment of the reflective surface.

Also, as compared to conventional flash tubes, anode and cathode leads **61** and **62** have an enlarged diameter, preferably approximately 0.100 inches. As seen on FIG. **5**, a pair of heat sink fins **65** extend radially outward from leads **61** and **62**. These structural features promote heat transfer away from flash tube **60**.

Of course, the air being circulated internal to flash head **13** must be cooled and, because the air cannot be exhausted, a novel air recirculation and cooling system is provided within flash head **13**. A shroud **48** and reflector **53** forms an air plenum around flash tube **60**. However, the diameter of plenum shroud **48** is selected so that when installed, an air passageway **64** is defined between the outer surface of plenum shroud **48** and the inner surface of flash head enclosure **56**. Accordingly, air circulated within flash head **13** by blower **51** is forced through air passageway **64** where it is cooled by coming into contact with housing **56**. Enclosure **56** is itself cooled by the effects of ambient water temperature when flash head **13** is submerged. Mounting brackets **43** mechanically attach parabolic reflector **53** to plenum shroud **48**. The blower **51** will preferably have a rating of at least 55 CFM at a static pressure of 0.4 inches of water.

Flash tube mount **46**, shroud **48** and blower **51** are secured to a sheet metal weldment **42**. The weldment **42** is attached to three support posts **65** (FIG. **19**) welded to housing **56**.

Flash head electrical components, shown in part on FIGS. **3**, **4**, **5**, or **6**, and schematically described with on to FIG. **9**, are electrically connected to one or more ceramic posts **44** arranged around and attached to the bottom wall of plenum shroud **48**.

One of the components mounted interior to flash head **13** but outside the space enclosed by plenum shroud **48** is a temperature sensor TS**101**. Temperature sensor TS**101** provides electrical signals responsive to the internal flash head temperature for use by system control unit **10** in monitoring and regulating the operation of each flash head **13**. In a preferred embodiment of flash head **13** as described, the safe internal temperature operating range is 14–122 degrees F.

To provide some level of thermal isolation of the electronic components of flash head **13** from the heat generating effects of flash tube **60**, a pair of opposed heat shields **45** extend vertically from the lower wall of plenum shroud **48** and up along the outer wall of duct **59** to a distance above the upper margin of the installed electrical components.

FIG. **9** is a schematic diagram of the electrical components and interconnections in flash head **13**. A series of wire terminals P1 through P11 (each of which corresponds to a ceramic post **44** on FIG. **6**) provide a connection point for the individual flash head power and communication wires contained within flash head power and control cable **17** (FIG. **1**). Thus, flash tube power is brought to the anode and cathode of flash tube **60** through terminals P1 and P2, respectively. The cathode power from flash head control unit **12** is also connected to the secondary winding on trigger transformer T**101**, through an R-C filter network RC**101**. The flash tube trigger signal is received from flash head control unit **12** at terminals P3 and P4 and, through de-coupling transformer T**102**, drives the primary winding of trigger transformer T**101** connected at terminals P8 and P9.

Terminals P4 and P5 of flash head **13** provide power to blower **51**, at blower motor start-up capacitor C**101**. Finally, temperature data is transmitted back to flash head control unit **12** from temperature sensor TS**101** through wires terminating in terminals P10 and P11.

FIG. **7** shows the physical location within flash head **13** of the wire terminals P1 through P11 and the other electrical components of FIG. **9**.

System Operation

The communications between the system control unit **11** and the flash head control units **12**, one for each group of 1 to 32 flash heads **13**, will consist of a standard RS-485 2-wire communications link. There will be a separate link for each flash head control unit **12**.

The format of all messages passed between a system control unit **11** and the flash head control units **12** will be consistent. Address **0** is reserved for use in broadcast messages. Flash head control units **12** will use their addresses in both sending and receiving messages. The system control unit **11** will listen to all messages and therefore requires no specific address. It will use the address to determine which flash head control unit **12** is sending a message.

Each message will have the following Message Format:

Byte **0**: Unit Address Message is for/from
Byte **1**: Message Type
Byte **2–3**: Message Length
Byte **4**-(n−1): Message Data
Byte n: Checksum

The communication scheme requires most messages to be acknowledged upon receipt. Messages requesting a response will accept the response as the acknowledgment. Other than broadcast or poll messages, messages not requesting a response require a separate ACK (message acknowledged) or NAK (message not acknowledged) to be sent. Broadcast messages are addressed to all devices so there is no use in one particular device responding. Poll Messages are sent by the system control unit **11** to a flash head control unit **12** to determine whether the flash head control unit **12** has new or changed information pending (i.e. an alarm or warning condition that has occurred). If a flash head control unit **12** has no information pending, it can ignore (not respond to) a Poll Message. If it has information pending, it should send the message when it receives a Poll.

ACK or NAK responses are based on several items: 1) correct checksum received; 2) correct #-of-bytes received (matches message length); 3) no communications errors detected (parity error, SW or HW overrun errors, etc.). ACKnowledging (or NAKing) the receipt of a message is performed regardless of whether the message type is processed by the receiving unit. This allows new messages to be created for other devices on the same communications link without modifying the software in all units. The capability to send variable length messages also allows new information required for one type of system control unit **11** to be added to an existing message without changing the software in all units. System control units **11** without upgraded software will only process the information they know about and will ignore new information added to the end of the message.

Communications messages from the system control unit **11** to the flash head control units **12** will include:

1. Set General Parameters (i.e. Date, Time, etc.);
2. Synchronize Now (begin flashing according to preset configuration parameter set up by flash sequence commands;
3. Set Current Flash Head Configuration for each flash head **13** including: a) Flashing or not; b) flash rate; c) flash intensity; d) Flash head A or B select, for flash wavelength/color selection; e) time delay from Sync signal used for sequencing flashes.
4. Set Present Flash Head configuration per flash head **13** including: a) Flashing or not; b) Flash rate; c) Flash intensity; d) flash head A or B select, for flash wavelength/color selection; e) time delay from Sync signal used for sequencing flashes.
5. Set Accessory Relays On/Off for: a) air bubble curtain; b) water jets; c) flash head/flash head control unit cooling fan.
6. Reset alarm and/or warning condition.
7. Request General Parameters (.e. Date, Time, etc.)
8. Request Software Version.
9. Request Current Flash Head Configuration per flash head **13**.
10. Request Present Flash Head Configuration per flash head **13**.
11. Request the status of Accessory Relays On/Off;
12. Request status of other inputs including water temperature (all depths).

The communications from each flash head control unit **12** to the system control unit **11** include:

1. General Parameters (i.e. date, time, etc.).
2. Software Version.
3. Alarm and Warning conditions.
4. Current Flash Head Configuration per flash head **13**.
5. Present Flash Head Configuration per flash head **13**.
6. Status of Accessory Relays On/Off.
7. Status of other inputs including water temperature.

For operator convenience and flexibility at system control unit **11**, the system application software loaded in personal computer **30** provides a user friendly graphical user interface (GUI) at video display **32**, such as provided by the Windows operating system. FIGS. **10**, **11**, **12**, and **13** illustrate typical GUI screens presented to the system operator at video display **32**. Thus, FIG. **10** is the screen that would be used by the operator when configuring communications with an operation of a specific flash head control unit **12**. The mouse selectable options available to the user on this screen include the enabling or disabling of a particular flash head **13** attached to that flash head control unit **12**, establishing the communications port location for that flash head control unit **12**, establishing the system address, enabling or disabling trigger and transformer monitoring functions, and enabling or disabling operation of the exhaust, circulation, and heat sense fans (blowers B1–B6).

FIG. **11** is the GUI screen presented to the operator for configuration of the flash sequence involving all of the flash heads **13** attached to system **10**. During this operation, the operator can set the flash order, flash timing, flash spacing, and similar sequence parameters.

FIG. **12** is the GUI screen presented to the operator at the time of configuration of a specific flash head **13**, connected to a particular flash head control unit **12**. Using the screen of FIG. **12**, the operator can either use overall system settings for the flash head or override the system settings, including selection of flash color (flash head A or B), flash rate, flash sequence delay, flash intensity, and (optionally) flash head position, which is adjusted using water jets (not shown) associated with that flash head **13**. Also, flash head triggering can be enabled or disabled as well as flash head cooling fan operation.

Finally, FIG. **13** is the GUI screen presented to the operator at system control unit **11** (or at a remote control location) reporting the status and function history of a particular flash head **13** over a particular operational interval.

Remote Control Operation

Preferably, the system **10** and system control unit **11** will be configured for remote operation by use of remote control and monitoring software installed on a personal computer that allows a user to dial into (via modem and telephone line), control and monitor system **10** from a remote location. This program can be used in place of or in addition to on-site personnel located at a system control unit **11** located at the system site.

The remote control and monitoring software handles the same communications and provides the same level of control and monitoring as the software used at system control unit **11**.

Typical System Installation

FIGS. **14**, **15**, and **16** illustrate a typical installation of system **10** near the underwater portion of a hydroelectric facility **100**, including four turbine intakes. Four flash head mounting racks **70***a*, **70***b*, **70***c*, and **70***d* extend vertically down the side wall of the structure **100**. Each flash head mounting rack **70** supports multiple flash heads **13** to provide a preferred pattern of flash illumination for fish who may approach the structure. A plurality of flash head control units **12** are attached on top of the structure **100** proximate the flash head racks **70** and connected by cables **15** and **17** (FIG. **1**). Preferably, the end portions of racks **70** are not submerged are attached to structure **100** in a hinged arrangement flash heads **13** can be accessed above water for any maintenance needed.

In a typical installation such as that shown in FIGS. **14**, **15**, and **16**, the flash heads **13** are operated at three hundred forty (340) flashes per minute with a typical flash intensity of 400 watts. There are a total of thirty-six (36) flash heads. This creates a "wall of light" in front of the turbine intakes. Assuming that turbine intakes **3** and **4** on FIG. **17** have fish bypass areas that allow for safe passage, fish can be guided to those areas by flashing the flash heads on the flash head racks **70** adjacent to turbine intakes **1** and **2** together. In addition, the flash intensities of the flash heads **13** on the flash head racks adjacent to turbine intakes **3** and **4** can be gradually decreased as the depth is decreased, directing the fish upward towards the safe passage area.

Thus, although there have been described particular embodiments of the present invention of a new and useful controllable stroke light system for control of fish, it is not intended that such references be construed as limitations upon the scope of this invention except as set forth in the following claims. Further, although there have been described certain operational parameters used in the preferred embodiment, it is not intended that such dimensions be construed as limitations upon the scope of this invention except as set forth in the following claims.

What is claimed is:

1. A system for directing the movement of fish in water near a man made structure, the system comprising:

a. a plurality of flash heads, each flash head including a flash tube means for generating one or more light pulses visible to fish proximate to the flash head, and a waterproof housing enclosing the flash tube means;

b. a system control unit operatively connected to each flash head and including processor means for causing the flash tube means to generate the light pulses in a predetermined flash sequence; and

c. the system control unit further comprising a command interface means for accepting system commands from an operator of the system, the system commands including flash sequence commands, the processor means including sequence command processing means for varying and executing the flash sequence in response to the flash sequence commands.

2. The system of claim **1**, the system control unit further comprising system monitor means for providing system status signals to the operator, the system status signals including flash sequence status signals corresponding to the flash sequence being executed by the processor means.

3. The system of claim **2**, wherein the processor means comprises a personal computer, the command interface means comprises a keyboard operatively connected to the personal computer, and the system monitor means comprises a video display operatively connected to the personal computer.

4. The system of claim **3**, the system control unit further comprising flash head signal receiver means for receiving flash head status signals from each flash head, the flash head status signals including a signal indicating whether a flash head is flashing or not flashing, and wherein the video system monitor means includes means for displaying the flash head status signals.

5. The system of claim **4**, the system commands entered by the operator including flash intensity commands, the system control unit further comprising flash intensity control means to adjust the intensity of the light pulses generated by each flash tube means in response to the flash intensity commands, and wherein the system status signals displayed on the video display include signals indicative of the flash intensity of each flash tube means.

6. The system of claim **5**, the flash head signal receiver means comprising a current sense transformer.

7. The system of claim **5**, the system commands entered by the operator including flash color commands, the system control unit further comprising flash color control means to adjust the color of the light pulses generated by each flash tube means in response to the flash color commands, and wherein the system status signals displayed on the video display include signals indicative of the flash color of each flash tube means.

8. The system of claim **5** further comprising flash head temperature control means to monitor and control the internal temperature of each flash head.

9. The system of claim **8** wherein the flash intensity control means is responsive to the flash head temperature control means.

10. The system of claim **9** wherein the flash sequence includes a flash rate for each flash tube means and wherein the personal computer includes means to adjust the flash rate for one or more flash heads in response to the flash head temperature control means.

11. The system of claim **9** wherein the flash head temperature control means comprises a blower internal to each flash head.

12. The system of claim **9**, the system control unit further comprising at least one flash head control unit operatively connected to each flash head and to the processor means.

13. A system for directing the movement of fish comprising multiple flash heads and means to control the flash heads, each flash head comprising a waterproof flash head housing, a flash tube mounted inside the flash head housing, and cooling means mounted internal to the housing for cooling the flash head.

14. The system of claim **13**, the flash head cooling means comprising a blower and each flash head further comprising an air plenum means for directing air around the flash tube.

15. The system of claim **14**, each flash head further comprising an air passageway between the side wall of the air plenum means and the housing.

16. The system of claim **15**, each flash head further comprising a light reflector, the light reflector forming part of the air plenum.

17. The system of claim **16**, each flash tube having electrode leads, and the electrode leads including cooling fins extending therefrom.

18. The system of claim **16**, the light reflector having a parabolic shape formed around and extending upward from the flash tube.

19. A system for directing the movement of fish proximate a structure located in a body of water comprising multiple flash heads submerged in the water and arranged in a pattern proximate the structure, control means operatively connected to each flash head to cause the multiple flash heads to produce through a flash head lens a sequence of flashes which are visible to the fish, and air curtain means to generate air bubbles proximate one or more of the flash heads.

20. The system of claim **19** further comprising submerged water jet means to remove scum from one or more flash head lenses by directing a stream of water at the lens.

21. The system of claim **20** further comprising temperature probe means positioned proximate one or more flash heads to provide a signal to the control means which is responsive to water temperature.

* * * * *